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ORIGINAL ARTICLES.

I.—The Genesis of Tungsten Ores.

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(*Continued from the May Number, p. 203.*)

Part II: Wolfram Lodes without Cassiterite.

As already stated in the first part of this paper, a regular gradation may be traced from the cassiterite-wolframite lodes to wolframite-quartz veins without cassiterite, a type which appears on the whole to be more common in America than elsewhere. In many cases this difference is clearly due to a more complete differentiation of the magma, but in other instances a purely igneous origin is less conclusively established. In Cornwall and other granitic areas a tin-wolfram lode can sometimes be traced continuously into a wolfram lode, and this again into a pure quartz vein. Here the pegmatitic origin of the lodes is demonstrated, and as a rule the wolfram is accompanied by fluorite and other recognized pneumatolytic minerals, as well as by sulphides similar to those found in the tin lodes. Thus the genetic connexion with the tin-bearing types is beyond doubt. In a few instances only wolfram is found in association with gold ores; the significance of this will be discussed in a later section.

One of the most interesting cases of quartz-wolfram veins without tinstone is seen in the Sierra de Cordoba in Argentina.[1] Here the veins occur in gneiss, and are actually traceable into a large granite mass of unknown age which is intruded into the gneiss. They are clearly pegmatitic differentiates of the granite. The wolfram occurs in large crystals in the quartz and in nests up to half a cubic metre in size. The chief minerals found in association with the wolfram are mica, apatite, fluorite, molybdenite, and chalcopyrite, and in the oxidation zone there are various oxidized copper minerals derived from the chalcopyrite. The abundance of apatite is notable and somewhat unusual in wolfram lodes. This is an instance of differentiation from a magma rich in volatile constituents, especially fluorine, but apparently without tin and boron.

Somewhat similar to the foregoing are some wolfram lodes found near Lircay in the province of Angaraes in Peru.[2] Two dykes or

[1] Bodenbender, "Die Wolfram-Minen der Sierra von Cordoba in der Argentinischen Republik": Zeits. für prakt. Geol., 1894, p. 409.

[2] De Habich, "Informe sobre los Jacimientos de Tungsteno de la Provincia de Angaraes": Boll. Cuerpo Ingen. de Minas del Peru, No. 11, p. 31, 1904.

veins, some 1·5 metres thick, and mainly consisting of quartz, carry wolframite, pyrite, and some gold. The wolframite occurs in thickenings of the veins, something like a chain of beads. Here there is little evidence of any kind of pneumatolytic action.

In the United States tungsten ores are very abundant in some localities, and the total output is now the largest of any country in the world. The tungsten boom of 1916 in the Western States has already been referred to. The chief producers are the states of Colorado, Arizona, and Nevada, while some important deposits of scheelite are now being largely worked in California. The most important area of all is undoubtedly Boulder County, Colorado, north-west of the city of Denver. The occurrences of wolfram ores here have been exhaustively described by Messrs. Hess and Schaller.[1] The ferberite area of Boulder County, of which the town of Nederland is the centre, lies on an elevated plateau some 8,000 feet above the sea, forming the eastern margin of the Rocky Mountain system. The country rock consists of biotite-hornblende granite, gneiss, and quartz-mica schist, all of pre-Cambrian age. The ferberite occurs in a group of veins striking south-west to north-east and accompanied by gold and silver veins of the same general trend. The gold veins are of two types, characterized by sulphides and tellurides respectively, and the ferberite veins are more closely connected with the telluride type of gold vein. The only gangue mineral of any importance is quartz; occasionally a little felspar is found, together with chalcedony and calcite. The sulphides actually found in the ferberite veins include only chalcopyrite, galena, and blende, and these only in small quantity. Some molybdenite has been recorded from one locality only. These veins are extraordinarily rich in ferberite, which sometimes comprises the greater part of the veins, being accompanied only by a little quartz. It is believed by Lindgren that these deposits are a product of comparatively recent thermal activity, and the association with tellurides is noteworthy.

At Leadville, Colorado, wolframite and scheelite are associated with quartz in pyrite-gold veins; the scheelite seems, as usual, to be somewhat later than the wolframite. These veins appear to be connected with a monzonite porphyry.[2]

In the Snake Range, White Pine County, Nevada, wolframite is found with scheelite, pyrite, fluorite, and a little gold and silver in veins connected with a granite-porphyry and cutting quartzites and slates. Here the presence of fluorite indicates pneumatolytic tendencies.[3]

In the Black Hills of Dakota tungsten ores occur in two very different forms: the first, seen at Etta Knob and Nigger Hill, has already been mentioned; the second type is quite unlike anything hitherto described. According to Irving,[4] the ore shoots of this area

[1] "Colorado Ferberite and the Wolframite Series": Bull. 583, U.S. Geol. Surv., 1914.

[2] Fitch and Loughlin, *Economic Geology*, vol. xi, p. 30, 1916.

[3] Weeks, Bull. 340, U.S. Geol. Surv., 1908, p. 263.

[4] Irving, Trans. Amer. Inst. Min. Eng., 1901, and Professional Paper No. 36, U.S. Geol. Surv., 1904, p. 363.

are mineralized patches in a dolomitic limestone of Cambrian age. They form flat horizontal masses, highly siliceous in composition, and containing pyrite, fluorite, barytes, and occasionally gypsum. The wolframite is specially associated with the barytes. There is also a small amount of vanadium minerals. This deposit appears to have been formed by gradual replacement of the calcareous country rock by highly siliceous solutions ascending from below, and the concentration at this particular horizon may have been determined by the presence of impervious strata above. The tungsten may be derived from the underlying Algonkian Series, where wolframite occurs in pegmatites with cassiterite. If this is so, this must be regarded as a case of secondary metasomatism, but the resemblance to the wolfram-gold ores of Colorado and Nevada must also be taken into account, and the tungsten-bearing solutions may really be of direct magmatic origin, of post-Cambrian date, and independent of the Algonkian tin-wolfram deposits below.

A very interesting and remarkable occurrence of wolframite at Trumbull, in Connecticut, is described by Hobbs.[1] An oval hill, some 1,000 feet long and 200 feet high, is composed of coarsely crystalline marble, with sills of epidiorite above and below. The ore-bodies occur along the plane of contact between the lower epidiorite sill and the marble, and are concentrated in the epidiorite just below the contact. The ore consists of both wolframite and scheelite intimately mixed, with a little pyrite. The marble near the contact contains many metamorphic minerals, especially scapolite and garnet. The contact deposit seems to have been fed by veins in the underlying rock, which contain quartz, felspar, fluorite, and topaz. There are also some pure quartz veins. All of these are evidently of the usual granite-pegmatite type, and their relation to the basic sills is not clear. It seems probable that the ore-bodies are really due to derivation from a granitic magma and that their association with the basic intrusions is purely fortuitous. The latter are evidently of the normal chlorine-bearing type, as shown by the development of scapolite in the metamorphosed limestone. The presence of much scheelite is easily accounted for by derivation of lime from the calcareous rock. This, then, is not a contact deposit in the ordinary sense of the word, since the metallic constituents, and especially the tungsten, do not seem to have been derived from the rock in which they actually occur. It seems much more likely to be an example of granitic metamorphism which has happened to act on a basic rock and a limestone, and has segregated some constituents from each, depositing them in combination at or near their plane of junction.

The tungsten ores of Canada have been exhaustively described by Walker[2] in a special report. They do not seem, so far as yet known, to be of much economic importance, though some of the lodes are or

[1] Hobbs, Bull. 213, U.S. Geol. Surv., 1903, p. 98; and Twenty-second Ann. Rep. U.S. Geol. Surv., 1901, p. 7.

[2] Walker, *Report on the Tungsten Ores of Canada*, Department of Mines, Ottawa, 1909. Also frequent references in the Annual Reports of the same department.

have been worked. In the Dominion deposits of wolframite and scheelite seem to be of almost equally common occurrence, but they do not show many features of theoretical interest. The only point needing to be mentioned is that in several instances wolframite has been found in quartz veins with scarcely any other metallic minerals; occasionally a little pyrite or chalcopyrite is found. In Inverness County, Cape Breton, for example, hübnerite is found in quartz veins with a little chalcopyrite. In York County, New Brunswick, wolframite occurs in quartz veins with molybdenite, pyrrhotite, arsenopyrite, and a little cassiterite; topaz and fluorite are found in the gangue; this is evidently a transitional type. In the Kootenay district of British Columbia wolframite is found in some quantity along with gold in quartz veins cutting granite and various Palæozoic rocks. Here little or no sulphide ore is to be found. In the Cariboo district wolframite occurs in veins with galena and pyrite, while in the Yukon it is found associated with native gold and bismuth. All these occurrences should be considered in connexion with the gold-tungsten ores of Colorado and Dakota; the general question of the relations of this type will be discussed later.

In most of the wolfram mines of Queensland, as before described, the ores are associated with large quantities of tinstone, the latter being in most cases the more valuable of the two, but at Mount Carbine tinstone is so small in amount as to be negligible. This may therefore be regarded as an occurrence belonging to the present section of the subject, although tinstone does occur in quantity in other parts of the same district. The ores occur in pegmatite dykes in connexion with granites intrusive into schists and slates, which are highly metamorphosed and are often intensely silicified. The plans of the workings show a network of interlacing veins, varying in size up to 6 feet wide, but usually about 2 feet. The gangue is variable in composition, sometimes it is wholly quartz, while other veins consist chiefly of felspar; in the mixed veins quartz usually predominates; muscovite is rare, while tourmaline and beryl also occur in small quantity. The only other metallic mineral found is a small quantity of molybdenite. Wolframite has been found in very large blocks, one weighing 6 tons, but it is more common in bladed and acicular forms. So far as the genesis of these deposits are concerned, it is quite evident that they were derived from a granitic magma, like the tinstone-wolframite ores of other parts of Northern Queensland; their occasional association with tinstone in the immediate neighbourhood is clear proof of a common origin, and it appears that the portion of the granitic magma which gave rise to the pegmatitic lodes of Mount Carbine itself had undergone a more than usually advanced degree of differentiation, so that the tin-wolfram-bearing fraction had been almost completely separated from the fraction carrying wolfram alone. The mechanism of this separation is uncertain, but it may be connected with differences in the freezing-point of compounds of tin and of tungsten respectively with the volatile elements of the magma, possibly the fluorides. From a consideration of the facts observed in other areas, such as Cornwall, it seems probable that tungsten is more volatile

than tin, or, what amounts to the same thing, has a lower freezing-point in certain compounds. If this be so, it would naturally be expected that tungsten minerals would tend to travel further from their original source than tin minerals, and in some instances it seems to be established that this is actually the case.

An unusual type of tungsten lode containing a considerable amount of titanium minerals is found in the Eastern Alps.[1] The other associates are molybdenite, beryl, quartz, felspar, and apatite. This is an unusual combination, since titanium minerals seem to be decidedly rare in tin-tungsten lodes.

Wolfram sometimes occurs in lead-silver lodes, as, for example, at Neudorf in the Harz, where it is accompanied by fluorite, but this association seems to be decidedly uncommon.

In concluding the descriptive portion of this section attention may be drawn to the remarkable fluorite veins of San Roque in Brazil described by Valentin.[2] Although not containing any tungsten ores, nevertheless there are affinities to the tungsten type, and these may be considered as the extreme case of this kind of differentiation. The veins consist almost exclusively of quartz and fluorite, the latter showing a great variety of colours. There is occasionally a little pyrite, but no other metallic minerals. These veins appear to be in close connexion with the intrusion of the granite of Achala, and represent the consolidation product of the last residue of the magma after the metallic constituents, if present, had been strained off and crystallized at higher temperatures.

Summary of Part II.

To sum up this part of the subject, it appears that the wolframite deposits without tinstone include a considerable number of types of very varying character. Some of them are clearly of direct magmatic origin, and formed in a manner exactly similar to the wolframite-cassiterite lodes of granite areas. That is to say, they are produced from the granitic magma by differentiation carried a stage further than in the case of the tin-bearing lodes, leading to a complete separation of tin and tungsten. This process may, in fact, be regarded as an example of fractional distillation on a large scale. The extreme case of this kind of differentiation is afforded by the quartz-fluorite veins of San Roque, which are analogous to the topaz veins of some tin-bearing areas.

But in addition to the foregoing comparatively simple case it will be seen that this class also includes several varieties of widely different origin; some of these may be due to peculiar forms of differentiation, whereas others are certainly metasomatic; for example, the replaced dolomite in the Black Hills. It is doubtful whether any true contact deposits occur; those hitherto assigned to this origin may be capable of explanation in some other way. Finally, in some areas our knowledge of the geological conditions is

[1] Weinschenk, "Die Minerallagerstätten des Gross-Venediger Stockes": Zeits. für Krist., vol. xxvi, 1896.

[2] Valentin, "Über das Flussspathvorkommen von San Roque": Zeits. für prakt. Geol., 1896, p. 104.

at present too incomplete to allow any conclusions to be formed as to the genesis of the ores.

Theoretical discussion of the facts set forth in this section will be postponed until after the scheelite deposits have been described, since in many instances the problems involved are very similar.

(To be continued.)

II.—Dolomitization and the Leicestershire Dolomites.

By L. M. Parsons, M.Sc. (Lond.), D.I.C., F.G.S.

(PLATE XI.)

Part I: Evidences of the Period of Dolomitization.

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1. Classification of Types.
2. Field Evidences.
3. Inherent Structural Evidences.
4. Selective Dolomitization.
5. The Absence or Presence of Fossils.
6. Classification of Petrological Types.
7. The Dense Yellow Dolomites of Breedon, etc.
8. The Red Ferruginous Dolomites of Breedon and Breedon Cloud.
9. The Barren Grey and Yellow Dolomites of Ticknall and Calke.
10. Fossiliferous Dolomitic Limestones of Ticknall and Calke.

IN the district north of Ashby-de-la-Zouch dolomitized Carboniferous Limestone crops out where the Leicestershire border adjoins that of South Derbyshire. The dolomites, which attain a thickness of nearly 900 feet in this area, have hitherto received very little attention. I therefore propose to give a short description of them with a view to ascertaining how far their mode of occurrence and structure afford additional examples of, or exceptions to, the usual conclusions adopted concerning the origin of dolomite. With this object in view I propose to give a brief resumé of the evidences generally relied upon to explain the origin of dolomite, before proceeding to describe the Leicestershire rocks.

1. Classification of Types.

If dolomites are classified as simply as possible according to the period at which the dolomitization[1] took place, well-defined classes, as enumerated below, may be recognized:—

Primary dolomites.	1. Those deposited as *clastic* rocks derived from pre-existing dolomite.
	2. Those *chemically precipitated* as dolomite, with or without the agency of organisms.
Secondary dolomites.	1. *Contemporaneous* dolomites, or those deposited as ordinary limestones which have been altered, soon after deposition, by the influence of magnesian salts in the sea in which the rocks were originally deposited.
	2. *Subsequent* dolomites deposited as ordinary limestones which have been altered by the influence of waters belonging to some period later than that during which the rocks were originally deposited.

[1] Throughout this article the term dolomitization signifies the production of dolomite, either primary or secondary.

With regard to this classification it must be noted that as some confusion has existed concerning the significance of the term "contemporaneous", that name is used here strictly to denote dolomites of secondary origin.

The term "subsequent" has a wider significance than that of "vein" dolomitization, as certain leached dolomites and some other dolomitized rocks of undoubted subsequent origin cannot be described adequately as vein dolomites, since some of them do not occur in association with veins and channels. Evidently vein dolomites constitute a subdivision of subsequent dolomites. It is now generally admitted that the majority of dolomites are of secondary origin, the contemporaneous class probably being more numerous than the subsequent, but certain cases of dolomitization appear to be explained most satisfactorily by the theory of primary deposition. Many chemical experiments have been performed in the endeavour to produce dolomite at different pressures and temperatures, but with limited success.[1] In spite of the comparative failure of these experimental attempts to produce dolomite artificially, the fact that it does occur in nature as a chemical precipitate is shown by its occurrence in mineral veins. It is very doubtful whether any reliable evidence can be obtained from experiments performed under conditions which may be quite unlike the natural conditions which existed in the seas of remote geological periods.

In determining the class to which a dolomite belongs, one must rely upon the collective evidence afforded by :—

Field relations,
Inherent structural features,
Selective dolomitization, and
The absence or presence of fossils.

Space permits only an incomplete survey of the phenomena connected with dolomitization, and a short discussion of the more reliable sources of evidence is all that is attempted.

2. Field Evidences.

(*a*) The occurrence of truly bedded dolomites associated with beds of such deposits as gypsum or rock salt is considered to support the view that the dolomite was primarily precipitated.[2]

(*b*) The theory of primary deposition is also supported by the occurrence of genuine beds of dolomite alternating with beds of limestone. In this case it is inferred that the dolomite was either chemically precipitated,[3] or laid down as a clastic deposit derived from a source different from that of the non-dolomitic limestone. Pseudo-interbedding, characterized by the failure of the dolomitization to conform accurately to bedding planes, the lateral transition of dolomite into limestone, and sometimes by a streaky development of

[1] See F. W. Clarke, "Data of Geo-chemistry": Bull. Geol. Surv. U.S.A., No. 616, p. 559, 1916.

[2] See Weigelin, *Neues Jahrb.*, Beil. Bd. xxxv, p. 628, 1913.

[3] Suess, *The Face of the Earth*, English translation, vol. ii, p. 262, 1906.

dolomite in the intervening limestone, is in favour of subsequent dolomitization.[1]

(*c*) The presence of interbedded conglomerates containing fragments of dolomite derived from older dolomites below would suggest that the dolomitization of the older beds was not of subsequent origin, and that the dolomitic material of the conglomerate was a primary clastic deposit.[2]

(*d*) The persistence of uniform bedded dolomites over a wide area without lateral transition into unaltered or poorly magnesian limestones is considered to be one of the strongest evidences in favour of contemporaneous dolomitization.[3] This conclusion receives further support if such dolomites occur at the same stratigraphical horizons in different areas, but the presence of dolomite at a certain horizon in one area and its absence at the same horizon in another area, does not necessarily indicate dolomitization of subsequent origin. Dolomite may have been formed in shallow water, while poorly dolomitic or unaltered limestones were being deposited further from the shore-line.[4]

(*e*) Should beds of dolomite be found, when traced laterally, to pass into unaltered or poorly magnesian limestones, the inference is in favour of subsequent dolomitization,[5] provided that other more conclusive evidence of a different origin is not forthcoming.

(*f*) A patchy development of dolomite and limestone due to rapid lateral transition from one into the other is a modification of (*e*), and lends support to a similar conclusion.[6] A patchy development of dolomite and limestone on a small scale, known as pseudo-brecciation, is discussed later.

(*g*) The evidence in favour of subsequent dolomitization is much stronger when an irregular or patchy development of dolomite is associated with faulting or jointing. In such cases it is obvious that the fault planes and joints have probably served as channels for percolating magnesian waters of a period subsequent to that during which the rock was originally deposited.[7] Dolomites of this class are properly described as vein dolomites.

(*h*) Faulting associated with extensive and non-patchy dolomites (*d*) appear to indicate that the faulting occurred after dolomitization.

While discussing field relations we may observe that great thickness of bedded dolomite has been considered to support the view that the dolomite was of primary origin, but since a thick mass of limestone may be dolomitized during a long period of subsidence,[8] as in the case of certain coral reefs, it is questionable whether mere thickness

[1] Calvin, Iowa Geol. Surv., vol. vii, p. 151, 1896.
[2] See *Swansea* (Mem. Geol. Surv.), 1907, p. 13.
[3] Dixon, *Swansea* (Mem. Geol. Surv.), 1907, p. 13.
[4] Id., p. 15.
[5] Hardman, Proc. Roy. Irish Acad., ser. II, vol. ii, p. 728, 1875–7.
[6] F. M. Van Tuyl, "The Origin of Dolomite": Iowa Geol. Surv., vol. xxv, p. 364, 1916.
[7] *The Geology of the South Wales Coal Fields* (Mem. Geol. Surv.), pt. ii, p. 33.
[8] Skeats, "On the Dolomites of the Southern Tyrol": Q.J.G.S., vol. lxi, p. 97, 1905.

can be considered to yield any reliable evidence concerning dolomitization in general.

3. Inherent Structural Evidences.

(*i*) The degree of idiomorphism of dolomite crystals may afford subsidiary evidence concerning the class to which the dolomite may be assigned.[1] In many cases where subsequent dolomitization is amply proved by other evidences, it is found that the rhombohedra are considerably more idiomorphic than those of most dolomites of undoubted contemporaneous or primary origin. In the latter cases there is a marked tendency of the crystals to interfere with one another, the resulting structure being a more or less granular mosaic.

(*j*) The size of the rhombohedra is usually larger in subsequent dolomites where the growth of crystals is less impeded than it is in contemporaneous and primary dolomites.[2]

(*k*) As in the case of idiomorphism and size, the degree of purity of a dolomite is suggestive, but by no means conclusive.[3]

Crystals of a primarily precipitated dolomite should, in general, be less contaminated with impurities than those of a dolomite of secondary origin, though a contemporaneous dolomite may attain a fair degree of purity. It is, perhaps, safer to place no reliance upon the degree of purity.

(*l*) The relation of iron oxides, particularly hæmatite, to the dolomite rhombohedra, affords one of the most reliable evidences concerning subsequent dolomitization.[4] When hæmatite is included either centrally or zonally in the rhombohedra the only possible conclusion is that the hæmatite was introduced at the time when the dolomitization took place. For instance, in a district where Trias comes above Carboniferous dolomites having zonal inclusions of hæmatite, the obvious inference is that the dolomitization was subsequent and associated with waters percolating through the Trias (see micro-photograph, Pl. XI, Fig. 1). On the other hand, should the hæmatite be only interstitial, the inference is that dolomitization took place before the introduction of iron oxide. In a case where Trias rests upon Carboniferous dolomites, the presence of only interstitial hæmatite in the dolomite would indicate that the dolomitization was certainly Pre-Triassic, perhaps contemporaneous. Inferences similar to those made from the presence of included hæmatite appear to be justified in cases where dolomitization is intimately associated with other ores such as galena and zinc blende.[5]

(*m*) The relation of rhombohedra to chert in cherty dolomites affords definite evidence with regard to the relative periods at which the dolomite and chert were respectively formed.[6] If rhombohedra occur enclosed by chert, the inference is that the dolomite was formed either before or simultaneously with the chert. On the

[1] See F. M. Van Tuyl, Iowa Geol. Surv., vol. xxv, p. 390 et seq., 1916.
[2] *Swansea* (Mem. Geol. Surv.), 1907, p. 16.
[3] F. M. Van Tuyl, Iowa Geol. Surv., vol. xxv, p. 319.
[4] *Swansea* (Mem. Geol. Surv.), 1907, pp. 15, 16.
[5] Schmidt, Trans. St. Louis Acad. Sci., vol. iii, No. 2, 1875, p. 246.
[6] H. H. Thomas, *Ammanford* (Mem. Geol. Surv.), 1907, p. 76.

other hand, should chert contain no included rhombohedra, the formation of chert must have preceded that of dolomite, though this does not necessarily prove subsequent dolomitization, since there is no indication of any great period of time having elapsed between the formation of chert and that of dolomite.

4. Selective Dolomitization.

The term "selective dolomitization" has been applied to certain phenomena in which the formation of dolomite occurs more in certain portions of rock, presumably the less coarsely crystalline and more unstable parts, than in other more resistant portions. One result of this differentiation is a rock of mottled appearance at times not unlike a breccia. The relations between the dolomitic and non-dolomitic portions of such rocks may afford evidence concerning the origin of the dolomite.

(*n*) Pseudo-brecciation, in which a limestone assumes a mottled appearance on account of a patchy development of dolomite on a small scale, can scarcely be considered to yield evidence analagous to that of patchy dolomitization on a larger scale (*f*). That a pseudo-breccia is unlikely to be due to the formation of primary dolomite appears to be a legitimate inference, but the question as to whether the dolomitization of any particular pseudo-breccia is contemporaneous or subsequent must be decided by inherent evidence other than that of mere mottling. Thus a rock of this kind in which hæmatite is merely interstitial may be referable to contemporaneous dolomitization.[1]

Any particular pseudo-breccia may supply evidence of its own origin, but cannot form the basis for a definite generalization concerning the mottling of dolomitic limestones. Each case must be considered on its own merits.

(*o*) A mottled appearance in which the dolomitic material is worm-like or fucoid suggests dolomitization facilitated by the presence of the remains of algæ or other organisms.[2]

Of particular interest are cases of fossiliferous dolomitic limestones in which selective dolomitization has differentiated between the matrix and organic structures. It frequently happens that in dolomitic rocks proved by general evidence to be of subsequent origin, the matrix, whether calcite or aragonite originally, has been largely converted into recrystallized calcite prior to dolomitization.[3] The recrystallized matrix, presumably on account of its relatively coarse texture, is apparently more stable than the original calcareous material of organic remains, consequently dolomite crystals have developed more in fossil structures than in the recrystallized matrix.

(*p*) Hence it is inferred that differential dolomitization of this kind may be an indication of subsequent alteration. That such an inference may not always be legitimate is evident from the occasional occurrence of dolomite crystals enclosed by recrystallized

[1] For instance, see *Swansea* (Mem. Geol. Surv.), 1907, pp. 14, 15.

[2] Peach & Horne, *North-West Highlands of Scotland* (Mem. Geol. Surv.), 1907, p. 366.

[3] *Swansea* (Mem. Geol. Surv.), 1907, p. 16.

calcite, suggesting that the dolomitization may have been contemporaneous.

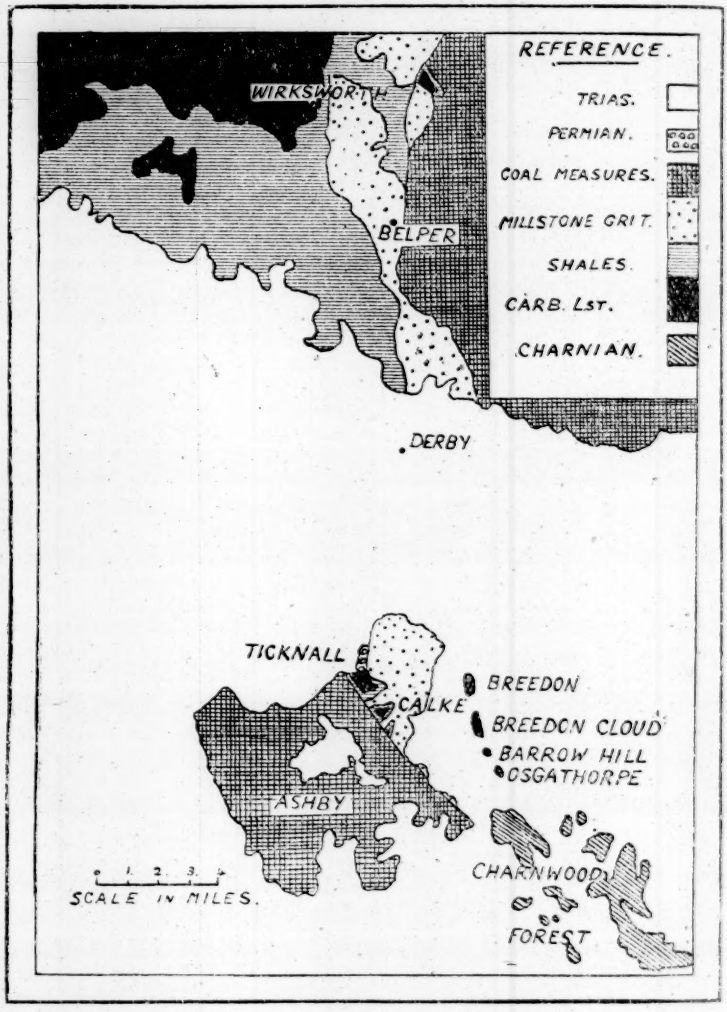
It has been shown that in certain contemporaneous dolomites, fossil structures, including corals, have resisted dolomitization to a greater extent than the matrix has done owing to the non-recrystallized material of the matrix being more unstable than the more coarsely crystalline material of organic remains.

(*q*) From this it may be inferred that the greater development of dolomite in the matrix than in fossil structures, including corals, is in favour of the theory of contemporaneous dolomitization.[1] But while this may be true in many cases, it is by no means certain that selective phenomena of this kind should always be relied upon to furnish conclusive evidence of the period of dolomitization. In connexion with the question of the relative stability of matrix and fossil structures, it must be remembered that the calcareous contents of dolomitic limestones may have consisted originally of any or all of the following forms of calcium carbonate: aragonite mud, more coarsely crystalline aragonite, calcite mud, and more coarsely crystalline calcite. Of these, aragonite mud is certainly the most easily converted into dolomite, and coarsely crystalline calcite is the most stable, but whether the more coarsely crystalline aragonite of coral tissues is more unstable than calcite mud appears to be an open question. It is just this point which weakens evidence afforded by selective dolomitization. In the contemporaneous alteration of a coral limestone containing few other organic remains, the matrix consisting mostly of aragonite mud would certainly be more easily dolomitized than the coarser coral structures.

Most organic limestones, however, consist largely of calcitic remains as well as coral structures, so that calcite mud must have been present originally in the matrix, and may even have been in excess of aragonite mud. If calcite mud is more susceptible to alteration than coarser aragonite, in contemporaneous dolomitization the matrix would still be dolomitized in preference to coral structures. On the other hand, should calcite mud be more stable than coarser aragonite, contemporaneous alteration of a mixed organic limestone would result in the development of dolomite more in coral structures than in the matrix. Again, there appears to be no means by which the proportions of aragonite and calcite muds in the original matrix may be ascertained. Considerations of this kind suggest that the phenomena of the selective dolomitization of organic rocks can scarcely be relied upon to supply sound evidence, particularly in cases where such phenomena appear to contradict the evidence afforded by field relations or other reliable features.

Selective alteration of oolitic limestones may be more reliable, since the differentiation in such cases is between coarser calcite and finer calcite. If dolomitization has attacked oöliths in preference to a recrystallized matrix, the alteration is probably subsequent; on the other hand, the development of dolomite more in a non-recrystallized matrix than in ooliths may indicate contemporaneous dolomitization.

[1] *Swansea* (Mem. Geol. Surv.), p. 15.



Map showing the position of the Leicestershire Dolomites compared with those of the Carboniferous Limestone of Derbyshire and of the Charnwood Pre-Cambrian.

5. The Absence or Presence of Fossils in Dolomites.

It is doubtful whether any reliable evidence of the period of dolomitization can be obtained from the absence of organic remains. A primarily precipitated dolomite would probably be deposited under conditions unfavourable to life, but it is also conceivable that either contemporaneous or subsequent dolomitization could be so complete as to obliterate all traces of organic structures that may have been

present originally. In other words, the final stage of secondary dolomitization might produce the complete alteration of a rock which may have exhibited selective phenomena in its early stages of alteration.

(*r*) The presence of fossils in a dolomite is a little more significant, particularly if they are at all numerous. The argument is then against the theory of primary precipitation. In a rock showing no selective features the condition of fossil structures as casts or as replacements in dolomite, appears to yield very little evidence of contemporaneous or subsequent alteration since both casts and replacements of the same class of organisms may occur in the same bed of dolomite.

The perfect replacement by dolomite of coral structures is certainly *suggestive* of contemporaneous alteration, since such replacements have been found to occur in modern reefs before calcitic recrystallization of coral tissues took place.[1]

Part II: The Leicestershire Dolomites.

A series of faulted inliers of Carboniferous dolomites extends in a north-westerly direction from the edge of Charnwood, commencing with small patches of dolomite at the village of Osgathorpe, and ending to the north in the mass forming Breedon Hill, a landmark for many miles. Between these limits of the series are situated the dolomite hill known as Breedon Cloud and the much smaller though petrologically similar inlier called Barrow Hill. In each of these cases the Carboniferous Limestone is surrounded by unconformable Keuper. A few miles to the west of Breedon there are small valley inliers of Lower Carboniferous rocks containing bedded dolomites and dolomitic limestones at Ticknall and Calke Park. At these localities the Lower Carboniferous is succeeded conformably by Millstone Grit, which is overstepped at one or two places by Trias.

6. Classification of Petrological Types.

Disregarding details of stratigraphy and palæontology which I have described in another paper,[2] and considering the formations purely from a petrological point of view without assuming the mode of origin of the dolomite, we may distinguish in the area different types of dolomitic rocks as follows:—

Dolomites proper, containing a proportion of magnesium carbonate approaching 40%	Dense yellow dolomites of Breedon and Breedon Cloud (1).[3]
	Red ferruginous dolomites of Breedon and Breedon Cloud (2).
	Barren grey and yellow dolomites of Ticknall (4).
Dolomitic limestones containing a relatively small percentage of magnesium carbonate	Fossiliferous dolomitic limestones of Ticknall and Calke (3).

[1] See Cullis, "The Atoll of Funafuti": Report of Coral Reef Committee, Royal Society, 1904, section xiv, p. 407.

[2] See Abstracts of the Proc. Geol. Soc. of London, No. 1004, March 14, 1917.

[3] The numbers in parentheses indicate relative stratigraphical positions in ascending order.

In this table the types predominating in the district are placed higher in the list.

7. The Dense Yellow Dolomites of Breedon, Breedon Cloud, etc.

The bulk of the dolomites of the two Breedons, Barrow Hill, and Osgathorpe consists of dense yellow material having a specific gravity and chemical composition approaching those of a pure dolomite. The proportion of Magnesium Carbonate varies slightly in different beds, but averages nearly 40 per cent, while iron compounds and insoluble residues are present in small amounts.

The field relations of these rocks are studied best at Breedon-on-the-Hill, where quarries are being worked in a direction at right angles to the strike. At this locality more than 800 feet of fairly thick-bedded dolomites succeed one another without any marked variation in petrological characters and without any apparent complications due to faulting. Though the chemical composition and texture of the material forming one stratum may be slightly different from that of another, the inherent characters of any particular bed appear to be uniform. The dolomitization is in no case patchy (*f*).[1] Laterally the beds do not pass into unaltered or poorly dolomitic limestones (*d*), though this fact would have greater significance if the Carboniferous Limestone of the area had a larger outcrop. The absence of faulting at Breedon suggests the improbability of subsequent vein dolomitization associated with dislocation (*g*). At Breedon Cloud strike faulting does occur, but is there associated with non-patchy yellow dolomites which do not pass laterally into unaltered limestone (*h*).

Conglomerates and pseudo-breccias are not present. Microscopic sections of the yellow dolomite of Breedon, Breedon Cloud, and Barrow Hill show a fine-grained crystalline structure composed mainly of small grains more or less allotriomorphic, though some rhombohedral outlines may be seen (*j* and *i*). The degree of purity is not high since minute dusky inclusions of insoluble matter are very numerous (*k*). There are no zonal or central inclusions of hæmatite, and what little iron oxide does occur, mainly limonite, is interstitial (*l*). Chert is absent from the material exposed in the workings of Breedon-on-the-Hill, though it occurs in the yellow dolomites of a higher horizon at Breedon Cloud. Sections do not show any dolomite rhombohedra in the chert (*m*). Fossils are not numerous at Breedon, Barrow Hill, and Osgathorpe; those that do occur at these localities consist chiefly of dolomite casts of Brachiopoda and a few corals. At Breedon Cloud, however, higher beds are exposed and fossils are more plentiful. Corals are preserved as dolomite replacements and as casts (*r*). *Syringopora* is usually found as casts, but *Michelinia*, *Campophyllum*, and other genera exhibit septa, tabulæ, and other structures beautifully preserved in minutely crystalline dolomite. Goniatites (*Glyphioceras*) also occur as dolomite replacements, but Brachiopoda are present as casts.

The conclusion to be drawn from the collective evidence concerning

[1] Italic letters in parentheses refer to corresponding evidences mentioned in the earlier part of the article.

the yellow dolomite of Breedon, etc., is undoubtedly in favour of contemporaneous dolomitization.

8. The Red Ferruginous Dolomites of Breedon and Breedon Cloud.

The uppermost portion of the Carboniferous Limestone sequence seen at Breedon and Breedon Cloud is composed of several feet of thinly bedded red dolomites quite distinct from the more massive yellow dolomites below. These red dolomites cannot be seen to pass laterally into unaltered limestone (*d*), but it must be remembered that the outcrop is not very extensive. The rock is patchy in the sense that the proportion of magnesium carbonate varies in any particular stratum, but there are no external appearances analogous to those of pseudo-brecciation (*n*). Faulting occurs at Breedon Cloud, though I infer that dislocation has not been a factor of the dolomitization for the following reasons: (1) no faulting occurs at Breedon-on-the-Hill where these red dolomites are otherwise precisely similar to the corresponding rocks at Breedon Cloud, (2) the faulting at Breedon Cloud is also associated with the yellow dolomites yielding very strong evidence of contemporaneous dolomitization (*h*).

Microscopic sections exhibit a structure characterized by idiomorphic, fairly large, and very impure rhombohedra (*i*, *j*, and *k*). Well-marked central and zonal inclusions of hæmatite occur in the crystals of dolomite forming these beds (*l*) (micro-photo, Pl. XI, Fig. 1). The outer zones of the crystals are free from hæmatite, but contain other inclusions similar to those in the rhombohedra of the yellow dolomites. A few streaks and patches of recrystallized calcite are present, and it is probable that this recrystallization took place prior to dolomitization.

It has yet to be proved whether coarsely crystalline calcite, either original or recrystallized, is under any particular conditions immune from alteration to dolomite. In connexion with this question, the condition of crinoid stems and ossicles in these red dolomites is interesting. Micro-photo, Pl. XI, Fig. 2, taken from a specimen of the Breedon rock, shows a crinoid ossicle invaded by hæmatite-bearing dolomite near the central passage and around the external margin, which is badly corroded by the alteration.

Other organic structures are obscure. That other fossils were present in these rocks originally, is shown by the occasional occurrence of coral and Brachiopod casts. It appears that we have here an instance of undoubted subsequent dolomitization in which both the matrix and organic structures, with the exception of encrinites, have been completely altered. Even crinoid remains, a most stable form of calcite, have been altered to some extent. With regard to the matrix, there is no way of ascertaining its original condition. It may have been calcite or aragonite, or a mixture of the two; or it may have been calcite recrystallized prior to dolomitization. Evidently this rock affords an illustration of the fact that conclusions are not easily made from phenomena connected with selective dolomitization.

The evidences concerning the origin of the Breedon and Breedon Cloud red dolomites indicate quite definitely that the dolomitization was subsequent and associated with waters percolating through the Trias, which formation rests upon the upturned edges of the red dolomites at these localities. It seems fairly evident that this subsequent dolomitization has attacked previously unaltered limestones (2)[1] lying between apparently contemporaneous dolomites stratigraphically lower (1) at the Breedons and higher (4) at Ticknall.

9. The Barren Grey and Yellow Dolomites of Ticknall and Calke.

About ten feet of bedded dolomites, yellow below but grey above, occur at the very top of the Carboniferous Limestone at Ticknall and Calke. They are succeeded by dark shales which pass up conformably into Millstone Grit. The chemical composition of these dolomites is similar to that of certain rocks described by Professor Skeats as "Dolomites of theoretical composition".[2] A comparison of the results of analysis makes this evident.

	Dolomite of theoretical composition (Skeats).	Ticknall grey dolomite.
Calcium carbonate . . .	54·7	57·1
Magnesium carbonate . . .	45·3	38·3
Iron compounds	—	2·7
Insoluble residue	·033	1·5

In the Ticknall dolomite a small amount of free calcite is present, as shown by slides stained with Lemberg's solution.

These rocks are seen best in the old lime works of Ticknall, but the exposures are very limited in extent, so that the bedded nature of these dolomites and their apparent non-passage into unaltered limestone cannot be used as reliable evidence of their origin (*d*). There is, on the other hand, not the slightest visible development of patchy dolomitization (*f*).

A small fault occurs, but this shows no definite connexion with the origin of the dolomite. The yellow and grey varieties of the rock are very similar in their microscopic characters. Sections show a crystalline mass in which a large number of crystals have been rounded off, presumably by simultaneous development (*i*), but some rhombohedral outlines are retained, particularly in the case of some of the larger crystals (micro-photo. Pl. XI, Fig. 3). There are very numerous inclusions, consisting mainly of minute particles of insoluble matter incorporated during crystallization (*k*), but there are no central nor zonal inclusions of hæmatite (*l*), iron oxide in the form of limonite being interstitial. This feature has special significance in view of the fact that reddish rocks of Permian and Triassic ages rest upon the limestone in the north-west corner of the Ticknall exposures. Chert is absent, and organic remains, if present originally, have been completely obliterated (*r*). According to the

[1] Numbers refer to stratigraphical positions given in the classification of petrological types.

[2] Q.J.G.S., 1905, p. 105.

evidence it seems reasonable to infer that the Ticknall dolomites are of contemporaneous origin.

10. Fossiliferous Dolomitic Limestones of Ticknall and Calke.

Certain limestones occurring at a slightly lower horizon than that of the barren dolomites of Ticknall, are interesting mainly on account of their representing an incomplete stage in the process of dolomitization. These limestones are best studied at Ticknall, but some of the Calke specimens yield very fine slides showing "selective" phenomena. The amount of magnesium carbonate does not exceed 16 per cent. As in the case of the barren dolomites above, these rocks occur apparently in definite beds and are not associated with faulting of any importance. Chert is absent. Microscopic sections show idiomorphic crystals of dolomite having a fair degree of purity (*k*), and devoid of zonal hæmatite inclusions (*l*). The rhombohedra show a decided preference for organic structures (*p*), both coralline and brachiopod, though dolomitization occurs to some extent in the matrix. Micro-photo, Pl. XI, Fig. 4, shows rhombohedra developed in organic structures, the matrix consisting of recrystallized calcite in places. Though the features shown by this photograph are typical, some individual crystals are developed partly in an organism and partly in the matrix. The rock being of a mixed organic nature, there is no knowledge of the relative proportions of aragonite and calcite muds in the original matrix, and even if this point could be decided there would still be the question of the comparative stability of coarser aragonite and of calcite mud to be determined. In one or two cases dolomite crystals are entirely surrounded by recrystallized calcite, from which it appears that either the recrystallization took place after the formation of dolomite or recrystallized calcite has been converted into dolomite. The inference that dolomitization was prior to recrystallization would tend to support the theory of contemporaneous origin. The selective phenomena exhibited by the Ticknall and Calke dolomitic limestones do not, in my opinion, yield any conclusive evidence concerning the period of dolomitization, and though the balance of evidence derived from other sources may be slightly in favour of contemporaneous alteration, it may be wiser to consider the matter "not proven" since some of the evidence is of a conflicting nature.

Having arrived at the general conclusion that most of the dolomites of the Leicestershire area are of contemporaneous origin, may I suggest that they appear to have been formed in shallow portions of the Carboniferous sea situated in the Charnwood region. The dolomitic nature of these rocks compared with that of the more normal limestones occurring at the same horizons (D_1 and D_2) in Derbyshire may thus be explained. The case may be somewhat similar to that of the *laminosa* dolomites of the Bristol area, which are situated about twenty-five miles distant from the more normal limestones of the Mendips. The presence of a rich Lamellibranch fauna in the D_2 subzone in Leicestershire, and the presence of only

a few feet of Carboniferous Limestone at places south of Osgathorpe as shown by a boring at Desford where the Carboniferous Limestone was found to rest on Pre-Cambrian, supply evidence that shallow-water conditions existed in the area during Carboniferous times.

EXPLANATION OF PLATE XI.

MICROPHOTOGRAPHS OF THE LEICESTERSHIRE DOLOMITES.

FIG. 1.—Red dolomite, Breedon, Leicestershire. Idiomorphic rhombohedra, having central zonal inclusions of hæmatite and fairly clear outer zones. × 25.

,, 2.—Red dolomite, Breedon. Calcite of crinoid ossicle invaded by fine-grained hæmatite-bearing dolomite. Matrix completely dolomitized. × 25.

,, 3.—Grey dolomite, Ticknall, south-eastern border of Derbyshire. A mosaic of rather allotriomorphic grains devoid of zonal hæmatite but having many dusky inclusions. A few rhombohedral outlines are shown. A little limonite is interstitial. × 25.

,, 4.—Fossiliferous dolomitic limestone, Calke Park, Derbyshire. Typical section showing preference of dolomite for organic structures. The matrix is partly composed of recrystallized calcite. × 25.

III.—THE GENUS *BOUCHARDIA* (BRACHIOPODA) AND THE AGE OF THE YOUNGER BEDS OF SEYMOUR ISLAND, WEST ANTARCTIC.

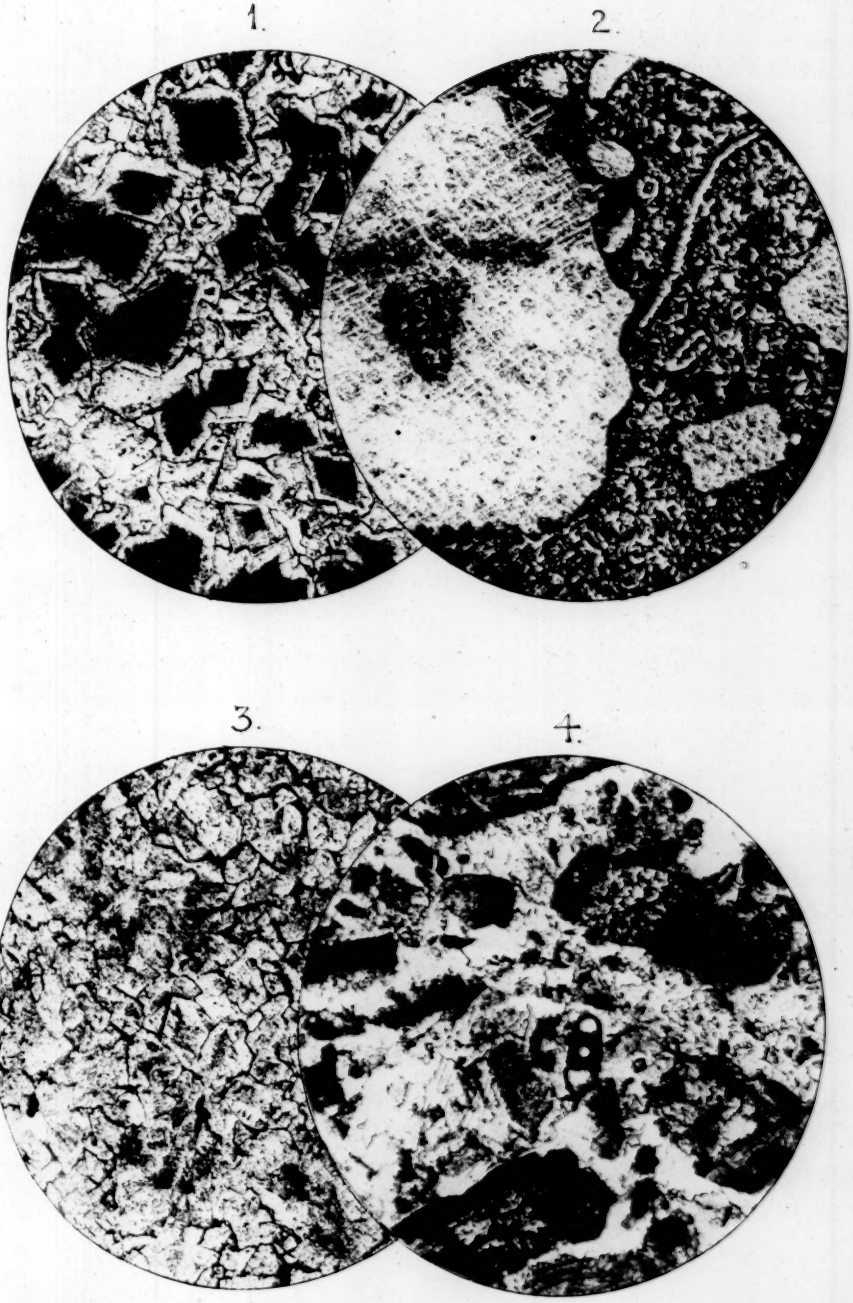
By J. ALLAN THOMSON, M.A., D.Sc., F.G.S., Director of the Dominion Museum, Wellington, N.Z.

THE AGE OF THE YOUNGER BEDS OF SEYMOUR ISLAND.

SHELLS with the external aspect of *Bouchardia* have been known for some time from the New Zealand Tertiary (Oamaruian), and were first described by Hutton in 1905[1] under the names of *Bouchardia rhizoida* and *B. tapirina*.[2] The correctness of this generic ascription was doubted by von Ihering, who stated that the shells lacked the characteristic external form of *Bouchardia*.[3] In this, however, von Ihering was mistaken, probably owing to the unsatisfactory nature of Hutton's figures, for these species agree externally with *Bouchardia* in the very characters which he supposes they lack, viz., the very sharp beak ridges, the more or less straight sides, and the presence of a longitudinal cord over the suture of the deltidial plates. The most characteristic external feature of the shell of *Bouchardia* is that the sharp beak ridges unite in an apex dorsally of the foramen, i.e. the foramen is epithyrid. In Hutton's supposed *Bouchardiæ* the foramen is permesothyrid, but almost epithyrid.

Buckman[4] has described a number of species of *Bouchardia* from the younger beds of Seymour Island, West Antarctic, and having to rely practically on these alone for a determination of the age of the beds, and finding no help in the way of direct zoological comparison, he has been forced to fall back on a biological argument.

[1] Trans. N.Z. Inst., vol. xxxvii, p. 480.
[2] Not *Waldheimia tapirina*, Hutton, 1873.
[3] Ann. Mus. Nac. Buenos Aires, t. xiv, p. 473, 1907.
[4] Wissensch. Ergebn. Schwed. Südpolar-Exped., Bd. iii, Lief. vii, pp. 14-17, 32, 1910.



C. S. Sweeting, photo. Hale, Imp.

LEICESTERSHIRE DOLOMITES.

"The *Bouchardiæ*, however, may be looked at from another aspect —the biological: their stage of development may be considered. In this respect they are intermediate between *Bouchardiæ* found in the Patagonian and in the Oligocene of New Zealand on the one hand, and the living *Bouchardia rosea* on the other; in fact they are, so far as biological development is concerned, much more advanced than the Patagonian Oligocene species, and much nearer in development to the present-day form.

"The character of the *Bouchardiæ* is wholly against their being earlier than the *Bouchardiæ* of the Patagonian. Biologically speaking, the *Bouchardiæ* of the Patagonian are earlier than the Antarctic *Bouchardiæ*, for they agree with the young stage and differ from the adult stages of these shells. Then the *Bouchardiæ* of the New Zealand Oligocene are certainly further removed from the Antarctic forms; they appear to be biologically earlier than the Patagonian species."

Recently I have been able to show[1] that the New Zealand supposed *Bouchardiæ* possess Magellaniform loops and septa, and further that in a series of shells with similar beak characters there are representatives with all stages of loop development between those of *Bouchardia* and *Magellania*. Arguing that the constancy of beak characters shows that we are dealing with a stock which has attained the Magellaniform loop in its highest member by a different line of ancestry from *Neothyris* and *Magellania*, I proposed new generic names for representatives of each loop stage as follows:—

Magadina: Genotype *Magadina browni*, Thomson. Loop Magadiniform, i.e. so-called Magadiform of Beecher.

Magadinella: Genotype *Magasella woodsiana*, Tate. Loop Terebratelliform.

Rhizothyris: Genotype *Bouchardia rhizoida*, Hutton. Loop Magellaniform.

Buckman[2] has since shown that in the position of the foramen there is development from the hypothyrid, through submesothyrid, mesothyrid, and permesothyrid to the epithyrid position. In this respect, therefore, *Rhizothyris* is less advanced than *Bouchardia*, and does not necessarily belong to the same stock. The similarity between them in beak characters is simply that in each the foramen is very advanced in position, and this may be and is the case in widely different stocks. *Laqueus*, for instance, also possesses a permesothyrid foramen, and is certainly no close relation of *Rhizothyris*.

Buckman's biological argument, therefore, is weakened by the inclusion of the New Zealand species of *Rhizothyris*, but it still stands if confined to species which there is no reason to suspect are not true *Bouchardiæ*. The most primitive in shape is *B. patagonica*, von Ihering, from the Salamancan (Upper Cretaceous) of Patagonia; then

[1] "Brachiopod Genera: The Position of Shells with Magaselliform Loops and of Shells with Bouchardiform Shape": Trans. N.Z. Inst., vol. xlvii, pp. 392–403, 1915.

[2] S. S. Buckman, "Terminology for Foraminal Development in Terebratuloids (Brachiopoda)": Trans. N.Z. Inst., vol. xlviii, pp. 130–2, 1916.

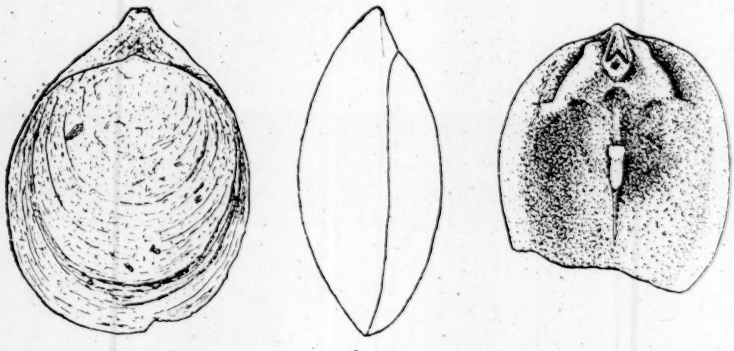
follow in order *B. zitteli*, von Ihering, from the lower Patagonian, *B. transplatina*, von Ihering, from the Entrerian of Patagonia, along with Buckman's Antarctic species, next the New Zealand Upper Oamaruian species described below, and finally *B. rosea*.

As a matter of fact, however, no such biological argument for the age of the Seymour Island beds was necessary, since a direct zoological comparison could have been made between *B. transplatina*, von Ihering,[1] and *B. angusta*, Buckman, which are hardly distinguishable from the published figures. In the absence of other evidence, this would justify the age of the younger beds of Seymour Island being placed as Entrerian, i.e. distinctly younger than the Patagonian and probably Upper Miocene, which is practically where Buckman placed them.

A New Species of *Bouchardia* from New Zealand.

Bouchardia minima, sp. nov. (Fig. 1.)

Shell elongate oval or elliptical, generally much longer than wide, greatest width about the middle, sides rounded in the broader forms,



a *b* *c*

Fig. 1.—*Bouchardia minima*, Thomson. Mt. Brown Beds, Waipara District, North Canterbury, New Zealand. (*a*) Holotype, dorsal view; (*b*) holotype, lateral view; (*c*) paratype, interior of dorsal valve, ventral view. Enlarged 6 diameters.

nearly straight in the narrower forms, front rounded, commissures with a low broad anterior sinuation. Valves rather depressed, the ventral slightly more convex than the dorsal and obscurely carinated. Hinge-line short and curved, beak short, acute, not incurved, beak ridges rather blunt, foramen minute, epithyrid, deltidial plates obscure, a groove running between the umbones of the two valves. Surface of valves smooth with a few moderate lines of growth, indicating development from a subcircular through an oval to an elliptical shape.

Interior of ventral valve:—Hinge teeth prominent, bifid, consisting of upper and lower processes separated by a well-marked groove;

[1] H. von Ihering, "Les mollusques fossiles du Tertiaire et du Crétacé supérieure de l'Argentine": Ann. Mus. Nac. Buenos Aires, t. xiv, pp. 480–1, 1907. Buckman unfortunately overlooked this reference in drawing up his bibliography.

there is a slightly raised ridge along the median line of the anterior part of the valve, probably separating the muscular impressions, which are not clear.

Interior of dorsal valve:—Posterior part much thickened with elevated solid cardinalia bounded on each side by deep hinge sockets which converge posteriorly. As in other species of *Bouchardia*, distinct socket ridges, hinge plates, cardinal process, etc., cannot be certainly distinguished. It would perhaps be more correct to term the socket walls in this case hinge teeth of the dorsal valve, for there is on each side a rounded projecting ridge which fits into the groove in the bifid teeth of the ventral valve. The space between the socket ridges is filled with shell matter, forming a solid platform, above which rises a median boss or cardinal process, rounded anteriorly, but with a small posterior tongue. From the sides of this boss two narrow ridges converge to meet near the umbo. In the anterior end of the solid hinge platform there are three caves entering from the floor of the shell, a larger and deeper median one and two smaller lateral ones, separated by two small projections. The high median septum is situated anteriorly and touches the median projection from the floor of the ventral valve. It rapidly lessens in height posteriorly and projects into the median cave of the hinge platform without uniting with the latter. On the anterior end of its elevated portion it bears a small swollen boss. No sign of the descending brachial arms has been observed in any of the numerous specimens examined.

Dimensions in millimetres:—

	Length.	Breadth.	Thickness.
Holotype	4·5	3	1·5
Paratypes	4·5	3	2
,, ...	5	4	1·8
,, ...	4	3	1·5

Type locality.—Base of main limestone, cuesta between Mt. Brown and the Waipara River, North Canterbury.

Material.—A large series (several hundreds) from the type locality, all from one small cave in the limestone; a few specimens from the same horizon in the Weka Pass end of the district; a small series from Flat Top Hill, Oamaru District, Otago.

Horizon.—The main Mt. Brown limestone is near the top of the sequence of Oamaruian beds of the Weka Pass and Waipara district, and probably correlates with the Hutchinson Quarry beds of Oamaru. It may therefore be called Upper Oamaruian. The limestone of Flat Top Hill is Ototaran, i.e. Middle Oamaruian. The Middle and Upper Oamaruian are by general consent Miocene.

Zoological comparison.—*Bouchardia minima* is to be compared with the other elongate species of the genus, from which it differs by the narrowness and curvature of the hinge-line. *B. antarctica*, Buckman, is an elongate form with a broad, nearly straight hinge, then follow with narrower and more curved hinges *B. attenuata*, Buckman, *B. rosea* (Maine), and finally *B. minima*, in the order named. If the development of elongation as revealed by the growth-lines is considered *B. minima* must be placed before *B. rosea*, since the youthful growth-lines are broader in the former.

Remarks on the genus *Bouchardia*.

Since an external form similar to that of *Bouchardia* may be combined with a more advanced loop, it is necessary before a given species can be certainly referred to the genus to have some knowledge of the interior arrangements. The loop is known only in the recent species *B. rosea*, and consists of two "anchor-shaped disconnected curved lamellæ" fixed to the posterior end of a high septum. These lamellæ resemble those of the ascending portion of the loop of *Magas*, and in both genera they are disconnected, and not united to form a ring as in *Magadina* and in the Magadiniform and pre-Magadiniform stages of *Terebratella*.[1] The descending branches of the loop, which are complete in *Magas* and *Magadina*, are totally absent in *B. rosea*. Beecher has compared the early pre-Magadiniform stages of *Terebratella* with the adult loop of *Bouchardia*, but there is this important difference, that in the young of *Terebratella* the growth of the descending branches commences before that of the ascending branches, and there is never a stage in which the ascending branches do not form a complete ring or hood on the septum.

If *Bouchardia* is correctly placed in the *Magellaninæ*, *B. rosea* must be looked upon as a retrograde species, descended from a form possessing a complete ring on the septum and incomplete descending branches, and now attaining a less instead of a greater calcification of the loop than its forerunners. If this view is correct, the loops of the fossil species of *Bouchardia* may be expected to show a greater calcification than exists in *B. rosea*. This expectation is not realized in *B. minima*, for numerous interiors of this species are available, but show no trace at all of a loop except a slight swelling on the posterior end of the septum which closely resembles the first stage of the hood in the young of *Terebratella rubicunda*. If this is a correct homology, then *Bouchardia minima* represents a still earlier loop stage than *B. rosea*, but is apparently also degenerate in that the descending branches are not calcified, since these appear first in the Terebratelliform development. The septum does not unite with the cardinalia in *B. minima*, which supports the view that its brachidium is in a less advanced stage than that of *B. rosea*.

Buckman states that many of the Antarctic *Bouchardiæ* examined by him were in such condition as to show the internal characters, but, unfortunately for the purposes of this discussion, he has given no further information than may be gleaned from an enlarged view of the interior of *B. angusta*. The characters of the cardinalia seem essentially similar to those of *B. minima* in the smaller of the two figures given, but little can be made of the nature of the loop if any exists. The case is still worse for *B. zitteli*, von Ihering, for von Ihering's figure is far from satisfactory. The interiors of the other species ascribed to *Bouchardia* have not been described or figured.

Von Ihering in 1907 argued from the then known distribution of *Bouchardia* only in the Salamancan and Patagonian of Patagonia and

[1] Cf. P. Fischer & D. P. Oehlert, "Mission scientifique du Cap Horn (1882–3): Brachiopodes": Bull. Soc. Hist. Nat. d'Autun, t. v, pp. 254–334, 1892. J. A. Thomson, "Additions to the knowledge of the Recent Brachiopoda of New Zealand": Trans. N.Z. Inst., vol. xlvii, pp. 404–9, 1915.

the Recent seas of Brazil that the genus originated in Patagonia. Since that date fossil representatives have been found in the West Antarctic and in New Zealand, but in younger beds than the Patagonian. Towards the end of the Miocene, then, the genus must have had a wide distribution in the Southern Ocean, which there is considerable reason to believe was much warmer than at present. Whether it attained this distribution by dispersion from Patagonia or not is hardly a matter for profitable discussion at present, since little or nothing is known of the Upper Cretaceous Brachiopods of New Zealand and the Antarctic.

IV.—Notes on the genus *Homalonotus*.

By F. R. Cowper Reed, Sc.D., F.G.S.

Since Salter,[1] in 1865, published his classification of the species of the genus *Homalonotus*, no detailed attempt has been made to re-arrange the increased number of species now known into natural groups. Salter was not convinced that his scheme was satisfactory, and appears to have regarded it as largely artificial, though convenient. The divisions instituted or recognized by him bore the names *Brongniartia*, Salter, 1865 (divided into two sections); *Trimerus*, Green, 1832; *Kœnigia*, Salter, 1865; *Dipleura*, Green, 1832; and *Burmeisteria*, Salter, 1865.

Koch & Kayser,[2] in 1883, after describing the Lower Devonian species of the genus from the Rhenish area and other regions, criticized Salter's system. The separation of *Homalonotus* and *Trimerus* was not considered sound, but *Dipleura* was acknowledged to mark a distinct group. The Lower Devonian species were grouped into two divisions, the first one containing two subdivisions, *Homalonotus* (which was regarded as equivalent to *Burmeisteria*) and *Trimerus*; the second division was formed by *Dipleura*. Primary importance was attached to the position of the point of section of the lateral margin or genal angle by the facial sutures, and secondary importance to the degree of furrowing of the pygidium. In the first division the facial sutures cut the margin in front of the genal angle, the thoracic axis is broader than the pleural lobes, the pygidium is parabolic with a blunt or pointed extremity, and has its axis and pleural lobes deeply furrowed. The presence or absence of spines distinguished the two subdivisions of this group. In the second division the facial sutures cut the middle of the genal angles, the pleural lobes are as wide as the axis, and the pygidium is bluntly rounded and either smooth or only weakly furrowed.

Bigot,[3] in 1888, recognized three sections of the genus, for which he employed Salter's group-names *Brongniartia*, *Homalonotus* sens. str. (= *Kœnigia*), and *Trimerus*, but he revived Corda's name

[1] Salter, Mon. Brit. Trilob., 1865, pp. 104, 105.

[2] Koch & Kayser, Abh. geol. specialk. Preuss., Bd. iv, Heft ii, pp. 73–157, 1883.

[3] Bigot, Bull. Soc. Géol. France, ser. III, vol. xvi, pp. 419–35, 1888.

Plesiacomia for a species *H. brevicaudatus* (Desl.), which he regarded as of independent generic rank.

Hall,[1] in the same year, acknowledged only one genus *Homalonotus*, and in his list of references quoted as synonyms *Dipleura*, *Trimerus*, *Plesiacomia*, *Brongniartia*, and *Kœnigia*.

Pompecki,[2] in 1898, put *Calymenella*, Bergeron, 1890, as a subgenus of *Homalonotus*, but did not refer to other previously established subgeneric groups.

Woodward,[3] in 1903, repeated Salter's definition of the genus (with a few alterations) in connexion with his remarks on British Devonian species, and recognized Salter's group, *Burmeisteria*, as valid.

Gürich,[4] in 1908, allowed only one genus, *Homalonotus*, but took *Brongniartia*, *Trimerus*, and *Kœnigia* as denoting subgenera of the Ordovician and Silurian periods.

Moberg & Grönwall,[5] in 1909, discussed Salter's system of classification of *Homalonotus* in connexion with their description of *H. Knighti*.

In 1909 Gürich[6] introduced a new subgeneric name *Digonus* for a Devonian group of species, and he considered the subgenera *Dipleura* and *Burmeisteria* as worthy of retention.

Woods,[7] in the same year, regarded *Homalonotus*, *Synhomalonotus* (Pompecki, 1898), and *Calymene* as of equal rank and placed them in the family Calymenidæ, but did not mention any subgeneric divisions.

Raymond,[8] in 1913, gave as three separate genera the groups *Homalonotus*, *Trimerus*, and *Dipleura*; but Beecher, in the earlier edition (1900) of the same textbook, mentioned only one genus, *Homalonotus*, with *Trimerus* as a subgenus.

A new Brazilian and Turkish subgenus of Lower Devonian age was established by Clarke,[9] in 1913, under the name *Schizopyge*, and the same author employed the name *Homalonotus* to include the type-species of Salter's *Burmeisteria*.

Generic, Subgeneric, or Group-names in use.

1. *Homalonotus*, König, 1825.

The type of the genus *Homalonotus* chosen by König is *H. Knighti*, König,[10] of the Upper Ludlow beds of England and Sweden. But the generic name has been used for many years in a comprehensive

[1] Hall, Palæont. New York, vol. vii, p. xxiii, 1888.
[2] Pompecki, Neues Jahrb. f. Miner. Geol., Bd. i, pp. 235–43, 1898.
[3] Woodward, Geol. Mag., Dec. IV, Vol. X, p. 28, 1903.
[4] Gürich, Leitfossilien, Lief. i, Camb. Silur., p. 70, pl. xxvi, figs. 1–3, 1908.
[5] Moberg & Grönwall, Om Fyled. Gotlands, Lunds Univ. Arssk., N.F., Af. ii, Bd. v, No. 1, pp. 72–7, 1909.
[6] Gürich, Leitfossilien, Lief. ii, Devon, pp. 155–7, 1909.
[7] Woods, *Crustacea and Arachnids*, vol. iv, Camb. Nat. Hist., section Trilobita, p. 249, 1909.
[8] Raymond, in Eastman-Zittel's *Textbook of Palæontology*, vol. i, p. 724, 1913.
[9] Clarke, Foss. Dev. Parana (Mon. Serv. Geol. Miner. Brasil, vol. i), pp. 89–101, 1913.
[10] König, *Icones Sectiles*, 1825, pl. vii, fig. 85.

manner, including many species which differ widely from the type. For this reason Salter,[1] in 1865, was led to suggest a new name, *Kœnigia*, for the section characterized by *H. Knighti*, and its characters are discussed below under that heading. Other authors have not been so precise, and Hall's[2] definition of *Homalonotus* strove to be wide enough to embrace the various divergent sections or groups, and has, therefore, a more extended application: "Body usually large, produced, depressed above, with abruptly sloping sides. Axial furrows indistinct or obsolete. Surface smooth or spinose. Cephalon depressed-convex, wider than long; genal angles rounded; anterior margin somewhat produced; glabella subrectangular, smooth, or with faint lateral furrows; eyes small, situated somewhat back of the middle of the shield; the facial sutures run from the genal angles over the eyes, converging towards the frontal margin, where they are connected by the transverse frontal suture, thence they continue to the edge of the doublure where they meet, thus inclosing a small, free, subtriangular plate. Thorax composed of thirteen deeply sulcate segments. Pygidium smaller than the cephalon, elongate triangular, posteriorly rounded or slightly produced. The axis bears usually from ten to fourteen annulations. Pleuræ smooth or with posteriorly sloping ribs." This definition, however, is not entirely satisfactory, for it is not applicable to the early Ordovician species, in which the axial furrows are distinct, and the number of segments in the pygidium fewer than stated. Hall also seems to regard the commissure uniting the facial sutures in front as not a part of them but as a new and separate structure, and he fails to remark that the epistomal sutures are distinct. His "subtriangular plate" is the epistome or rostral shield. It should, moreover, be added that the thoracic pleuræ always have rounded ends, and that the pygidium exhibits two main and separate types, one semicircular or semi-elliptical and simply rounded, the other triangular and acuminate behind.

The point of section of the margin by the posterior branch of the facial suture is also of some importance; Hall shows it in his diagrammatic woodcut as bisecting the rounded genal angle; but this is not always the case, as Koch (op. cit.) noticed and used as a basis of classification.

Salter's[3] earlier definition in 1865 makes no reference to the pygidial characters nor to the facial sutures, but it says that the genus is distinguished from *Calymene*, "its near ally," by its want of distinct trilobation, and goes on to state that "*Homalonotus* is elongate, convex, with steep sides and a very broad axis, scarcely distinguished from the pleuræ. There are thirteen body-rings deeply grooved, and the fulcrum is close to the axis in most of the species. The head with an obscure quadrate glabella, slightly lobed; a rostral shield; and a quadrate labrum (= hypostome) tuberculate and gibbous in the middle and with a bilobed tip. Surface of the body scabrous,

[1] Salter, Mon. Brit. Trilob., p. 106.
[2] Hall, Palæont. New York, vol. vii, p. xxiv, 1888.
[3] Salter, Mon. Brit. Trilob., p. 104.

occasionally spinous. Internally the cheeks have at their base a broad flat space next the glabella".

Raymond (op. cit., 1913, p. 724) defines *Homalonotus* as follows: "Axial lobe wide, cephalon short and trilobate in front, cheeks forming high mounds crowned by the eyes." Apparently he had in his mind *H. Knighti*, and at any rate this definition would not include any of the Ordovician species, and none of them can be put in *Trimerus* or *Dipleura*, which are the only other Homalonotid genera which he quotes.

Woodward,[1] in 1903, practically repeated Salter's definition in slightly different phraseology, saying: "The peculiar trilobation of the body-rings, so conspicuous in most genera, is very indistinct in *Homalonotus*, especially in the thoracic segments, although in some species it is better marked in the pygidium. The shape of the body is elongate, convex, with steep sides and a very broad axis, scarcely distinguished from the pleuræ. There are thirteen body-rings, deeply grooved, and the fulcrum is close to the axis in most of the species. The head is triangular, with an obscure quadrate glabella slightly lobed and a quadrate labrum; the surface of the body is scabrous, occasionally spinous. The pygidium is generally narrow and pointed, except in a few species which have a more rounded contour." He goes on to say that "of the twenty species recorded, by far the larger number are from the Silurian". It will be shown in this paper that the climax of the development of the genus is in the Devonian period, where the number of species and the diversity of types are greatest.

2. *Trimerus*, Green, 1832.

The type of this section or subgenus is the well-known *H. delphinocephalus*, Green,[2] first described from the Niagara Limestone of New York and subsequently recognized in the Wenlock Limestone of Dudley (according to Salter[3] it is the Woolhope Limestone). Salter (op. cit.) defined this section as follows: "Elongate, convex, with triangular head; eyes not remote; a defined but obscurely lobed broad glabella. Thorax slightly lobed; tail many ribbed, pointed, often acuminate." Raymond (op. cit., p. 724) merely states that the "cephalon is longer than in the preceding [i.e. *Homalonotus*], not trilobate in front, free cheeks narrow". There seems to be some difference in the British and American specimens as regards the glabella, for Hall[4] does not mention or figure any glabellar lobes or furrows in his description of the Niagaran types, while in most of the Dudley specimens two pairs of more or less faint subcircular lateral swellings, not touching the axial furrows, are present on the posterior half of the glabella and seem to represent the two posterior pairs of lateral lobes, and there is also a weak trace of the first lateral furrows.

The peculiar subcircular areas on each side of the base of the

[1] Woodward, GEOL. MAG., Dec. IV, Vol. X, p. 28, 1903.
[2] Green, Monthly Amer. Journ. Geol., vol. i, p. 559, pl. O, fig. 1, 1832.
[3] Salter, op. cit., p. 115.
[4] Hall, Palæont. N.Y., vol. ii, p. 309, pl. lxviii, figs. 1–14.

glabella, such as Salter[1] specially noticed in the South African species *H. Herscheli*, are also present in *H. delphinocephalus*; these areas may be marked off by a faint curved furrow or have a slight independent convexity, but are also distinguished from the rest of the cheeks by their smoothness and absence of pitting. They may be termed the *paraglabellar areas* (for further remarks see *Kœnigia* and *Burmeisteria*).

The epistomal sutures are very short on the upper surface of the head-shield and usually difficult to distinguish, but they are at right angles to the conjoint facial sutures and arise in front at a distance apart rather less than the anterior width of the glabella.

The course of the facial sutures themselves on the head-shield is usually well seen; Hall (op. cit.) describes them as "parallel and coincident with or slightly within the flexure of the margin, passing then obliquely through the eyes and turning [to] come to the margin a little above the posterior angle of the head-shield". They meet in front on the upper surface at an angle forming a more or less pointed Gothic arch close to the anterior margin and leaving a wide area before the glabella.

In one specimen in the Sedgwick Museum (Tablet No. 114) from the Wenlock Shale of Dudley, the inferior surface of the front part of the head-shield is shown; the doublure, which is broad, flattened and subcrescentic in shape with the posterior margin forming a double sigmoidal curve, reaches back to the front end of the glabella; the epistomal sutures are straight and converge posteriorly, thus defining a flat elongated triangular epistome which does not appear to have been described or figured in the case of British examples of the species.

In the case of the thorax of the type-species it should be mentioned that each segment of the axis has an anterior articulating band which is separated off by a furrow which bends back gradually before reaching the axial furrows and crosses the pleura obliquely. The axial furrows of the thorax are not in the same longitudinal line as those defining the glabella, for the axial furrows of the head-shield on crossing the occipital ring diverge obliquely outwards. There are, however, no well-defined axial furrows at all on the thorax, faint longitudinal depressions only being present in conjunction with a slight constriction of the pleura. At this point also, on each segment, there is situated the inner angle of the large triangular articulating facet extending to the end of the pleura and forming a bevelled flattened surface with a sharp, angulated posterior edge which crosses the pleural furrow obliquely without diverting its course. Barrande's[2] figure of a body-ring of *H. delphinocephalus* gives an erroneous idea of its characters, for it fails to show that the furrow which marks off the articulating band on the anterior of the axial ring, is continued across the pleura and articulating facet as the pleural furrow. Hall (op. cit.) describes it more clearly than Salter, who does not make it plain that this furrow is continuous.

Of other species referable to this section Salter mentions two, *H. Johannis*, Salt., and *H. cylindricus*, Salt., both from the Silurian.

[1] Salter, Trans. Geol. Soc., ser. II, vol. vii, p. 216, pl. xxiv, fig. 1*c*, 1856.
[2] Barrande, Syst. Silur. Bohême, vol. i, pl. v, fig. 10.

The former, however, should be placed in the section *Kænigia* according to the structure of the front margin of the head-shield, which Salter failed to observe from want of well-preserved specimens. But *H. cylindricus* is undoubtedly a member of *Trimerus* so far as its pygidium is concerned, and it was on this part that the species was based. Salter's[1] outline-sketch of a middle-shield (of which the specimen cannot be traced), which he thought might belong to this species, shows the facial sutures uniting in front in a much flattened curve, but there is nothing in other respects to prevent its reference to the same section as *H. delphinocephalus*.

3. *Dipleura*, Green, 1832.

This section or subgenus was founded on the well-known American species *H. Dekayi*, Green,[2] from the Hamilton Group (Middle Devonian).

Salter (op. cit., p. 105) defines the section as follows: "Convex, head wide, semi-oval or subtriangular, with somewhat pointed front. Glabella narrow, well defined. Eyes rather remote, on gibbous cheeks. Thorax slightly lobed. Tail obtuse, hardly ribbed." No British representatives are recorded, but Salter refers to it the Continental species *H. obtusus*, Sandb., and probably *H. crassicauda*, Sandb., and *H. Ahrendi*, Roem.

Raymond (op. cit.) briefly defines *Dipleura* as follows: "Axial lobe wide, pygidium smooth."

Hall[3] has given a full description of the species, and we may quote his description of the course of the facial sutures: "The facial sutures take their origin on the lateral margins of the doublure in front of the genal angles and pass inward, parallel to the posterior margin of the cephalon, to the eye, thence forward with a broad curve inward to the anterior margin at the base of the prora, bending thence on to the epistomal doublure, meeting at its inferior margin. The branches of the facial suture are united on the upper surface of the prora by a straight transverse frontal suture, thus leaving a free median plate upon the epistoma, which is elongate-subtriangular in outline, attenuate at the apex, and recurved at the base, which forms the anterior portion of the prora." The connecting "frontal suture" here described, judging from the manner in which the facial sutures bend inwards and are connected in front of the glabella in *H. noticus*, Clarke, and other species, must be regarded as merely the anterior deflected part of the facial sutures, while the so-called continuations of the facial sutures over the anterior edge which bound the epistomal plate laterally on the inferior surface of the head-shield must correspond with the epistomal sutures of other species.

Here, as in *H. ornatus*, *H. rhenanus*, and other Devonian species, the flattening of the anterior curve of the anterior conjoint portion of the facial sutures gives a spurious appearance of an abnormal

[1] Salter, op. cit., p. 117, fig. 28.

[2] Green, Mon. Trilob. N. Amer., 1832, p. 79, pl. i, figs. 8, 9.

[3] Hall, Palæont. New York, vol. vii, p. 7, pl. ii, figs. 1–11; pl. iii, figs. 1–5; pl. iv, figs. 1–6; pl. v, figs. 1–10, 1888.

transverse and nearly straight special suture on the upper surface of the head-shield. It is not clear if Hall regarded this "frontal suture" as a new independent commissure originating by itself, but he apparently believed the facial sutures did not meet on the upper surface of the head-shield, but that they were directly continued by the epistomal sutures extending on to the inferior surface.

With regard to the existence of any distinctive features of this section, the structure of the epistomal doublure resembles *Tr. delphinocephalus*, and the thorax seems almost identical; but, as Hall (op. cit., p. 10) remarks, *Dipleura* differs from the *Homalonoti* of the earlier Devonian and Silurian of America and Europe in the obsolescence of the annulations of the pygidium at maturity. The hypostome is subquadrate, with the posterior margin broadly excavated, and is much like that of *Tr. delphinocephalus*. The glabella has three pairs of lateral furrows, which become obsolete at an early stage of growth. As regards the structure of the head-shield and the flattened anterior junction of the facial sutures, we may compare *H. rhenanus*, Koch,[1] and *H. ornatus*, Koch,[2] but as regards the obsolescence of the pygidial axis we see an approach to *H. lævicauda*, Quenst.,[3] though the head-shield and outline of the pygidium are distinct in that species.

Kayser, in a footnote to Koch's paper (op. cit., p. 10), rightly points out that the Rhenish Devonian species *H. crassicauda*, Sandb., and *H. Ahrendi*, Roem., mentioned by Salter under *Dipleura*, do not strictly belong to this group on account of their strongly ribbed and acuminate pygidia, but that *H. Schusteri*, Roem.,[4] may be referred to it.

4. *Brongniartia*, Salter, 1865.

The definition of *Brongniartia* given by Salter[5] is as follows: "Depressed, with broad rounded head, remote eyes, well-defined lobeless urceolate glabella, and many-ribbed rounded tail."

Two divisions were established by Salter with the following brief summary of characters: "(1) Body scarcely trilobed; the axis broad (*H. bisulcatus* is the type of the subgenus and of this section); (2) body strongly trilobed; the axis narrow (type, *H. rudis*; this leads off directly towards *Calymene*)."

Before discussing the characters and value of this subgenus proposed by Salter we must remark that it is unfortunate that he chose the preoccupied name *Brongniartia*. For Leach in 1824 used it for a genus of Coleoptera, and Eaton[6] in March, 1832, proposed it for a new genus of Trilobites, of which his *Brongniartia carcinodea*[7] was chosen as the type. The latter species, however, is now considered as identical with Green's *Triarthrus becki*. Eaton in June of the same year

[1] Koch, op. cit., p. 32, pl. iii, figs. 1-3.
[2] Ibid., p. 23, pl. ii, figs. 1, 2.
[3] Koch, op. cit., p. 55, pl. viii, fig. 4.
[4] Roemer, Beitr. z. Kennt. Nordwest Harz., iii, t. iii, fig. 20, 1855.
[5] Salter, op. cit., p. 104.
[6] Eaton, Amer. Journ. Sci., ser. I, vol. xxii, p. 165, 1832.
[7] Eaton, *Geol. Text-book*, 2nd ed., June, 1832, p. 33, pl. i, fig. 3.

figured as further examples of the genus the Trilobites *B. platycephala*[1] (= *H. Dekayi*, Green) and *B. isotelea*[2] (= *Asaphus platycephalus*, Stokes). Vogdes[3] puts *B. platycephala*, Eaton, as a synonym of *H. delphinocephalus*, Green. It is obvious from these facts that the name *Brongniartia* cannot be retained for Salter's group of *Homalonotus*.

The type of the group must now be considered. This species, *H. bisulcatus*, was founded by Salter[4] on specimens in the Geological Society's Collection and in the Woodwardian [Sedgwick] Museum, Cambridge. The first figured specimen, a middle-shield (op. cit., fig. 24), is stated in the text of McCoy's *Synopsis* to be from the "Caradoc Sandstone, Wittingslow, near Acton Scott, Shropshire", but in the explanation of the plate is stated (in error) to be from "S.W. of Pwllheli". The imperfect thorax and pygidium depicted in his fig. 26 and the separate pygidium (fig. 27) are from the same locality in Shropshire, and all these three specimens are in the Geological Society's Collection, now in the British Museum (Natural History), South Kensington. The specimens from which figs. 25 and 28 were drawn are in the Sedgwick Museum, and came from the Welsh locality south-west of Pwllheli. Three other specimens (figs. 29–31) are referred by Salter to a variety *β minor*, and are also at Cambridge. But the chief point to be emphasized is that the species is undoubtedly founded on the Shropshire specimens, and it is by them that its characters are fixed.

Salter[5] in his monograph in 1865 figured several examples from other Welsh localities, but stretched the limits of the species in including some of them; the first figures on his plate (pl. x, figs. 3, 4) are of those specimens from Wittingslow which he had used in his previous description in 1852 and had there figured.

In his first subsection of *Brongniartia* Salter put also his species *H. Sedgwicki* and *H. Edgelli*; the former was founded on two broken middle-shields in the Woodwardian Museum and calls for no special mention in this place, except with regard to the much flattened and wide curvature of the union of the facial sutures, which makes the head-shield (as Salter says) truncate in front and unusually broad. The second species was founded on a pygidium, but a doubtful middle-shield from Horderly was also ascribed to it.

We must, however, return to a consideration of the characters of the typical *H. bisulcatus*, for Salter's first description in 1852 is too brief, and his second description in 1865 is inaccurate, for it includes the ambiguous Welsh specimens, some of which at any rate ought probably to be separated off. Confusion is introduced by Salter's conflicting statements that the "body is scarcely trilobed" (p. 104)

[1] Eaton, op. cit., pl. ii, fig. 20.

[2] Ibid., pl. ii, fig. 22.

[3] Vogdes, Bibliogr. Palæoz. Crust. (Occas. Papers Calif. Acad. Sci., iv, p. 311, 1893); Weller, Bull. iv, pt. ii, Nat. Hist. Surv., Chicago Acad. Sci., 1907, p. 200.

[4] Salter, Appendix to M'Coy's Syn. Brit. Paleoz. Foss. Woodw. Mus., 1852, p. v, pl. i G, figs. 24–8.

[5] Id., Mon. Brit. Trilob., 1865, p. 105, pl. x, figs. 3–10.

and that the "trilobation is conspicuous but not deep" (p. 105). The latter statement is made for the type species and is incorrect, the axial furrows being very shallow and the pleural portions of the thorax scarcely marked off from the axis in the general convexity of the body. In the pygidium, however, the axis is well defined, has an independent convexity and well-marked though not deeply impressed axial furrows. In the thorax the axial furrows form continuous depressions, but each axial ring is independently marked off from its pleura by a short oblique transverse furrow corresponding to the one crossing the neck ring from the base of the glabella, which Salter mentions and shows in his figure (woodcut 24 on p. 106). The base of each pleura is somewhat swollen in the angle between this transverse furrow and the pleural furrow which is a lateral continuation of the furrow separating off the articulating band on the axial ring. There is a peg-like interior projection situated on the posterior margin of the thoracic ring just inside the posterior end of the short transverse furrow, and this peg or knob fits into a small corresponding notch on the anterior margin of the succeeding ring. Salter shows this structure (op. cit., pl. x, fig. 16) in his figure of a segment of *H. Brongniarti*, Desl., but does not describe it in connexion with *H. bisulcatus*.

In the case of the pygidium the shape is semi-oval or parabolic in all the typical Shropshire specimens; the so-called "young one" from North Wales, figured by Salter (op. cit., pl. x, fig. 8), is certainly different. Salter's description of the typical form, however, is correct, and it is important to notice that the axis is composed of 11–12 rings and is continued to the margin by a "conical appendage" or post-axial angulated triangular piece. There is also a distinct (though very narrow) flattened or gently concave border, not sharply defined from the rest of the pleural lobes, but the pleuræ do not cross it. The first sulcus crossing the lateral lobes is a direct continuation of the one on the axis which separates off the articulating band at its front end; we may therefore suspect that the second similar strong one is of the same nature, and therefore not a true interpleural furrow but homologous with the pleural furrows of the thorax. This opens up a curious question as to the nature of the so-called pleuræ on the pygidium. It was from the presence of these two strong furrows that Salter termed the species *bisulcatus*.

The original Welsh specimens from the Bala beds south-west of Pwllheli which Salter referred to *H. bisulcatus* and figured as such in 1852[1] are undoubtedly distinct from the Shropshire types; the middle-shield (fig. 25), by its breadth, shortness, and flattened anterior edge, suggests a reference to *H. Sedgwicki*, and perhaps the pygidium (fig. 28) may belong to the same species. But both specimens are poor, crushed, and distorted.

The other Welsh specimen figured as *H. bisulcatus* in his monograph in 1865 (pl. x, fig. 6) is likewise much distorted; it is from Moel y Garnedd, Bala, and together with some similar fragments in the Jermyn Street Museum ($\frac{3}{4}^{5}$, $\frac{3}{2}^{5}$, $\frac{3}{1}^{5}$) from the same locality may belong to a new species.

[1] Salter, op. cit., pl. i G, figs. 25, 28.

The so-called "young specimens" from Wales which Salter figured in 1865 (pl. x, figs. 7, 8) must certainly be separated from the typical *H. bisulcatus* and are the same as Salter figured in 1852[1] as his var. *β minor* from Maes Meillion. The poor specimen in the Sedgwick Museum from the Arenig beds of Ty Obry, figured[2] as *H. bisulcatus* with a query, is of very doubtful specific and even generic reference.

In the head-shield of the typical Shropshire examples of *H. bisulcatus* the facial sutures unite very close to the margin, or actually along its edge in a broad flattened curve leaving a wide pre-glabellar area at least one-third the length of the glabella. There is therefore no distinct, much less large, pre-sutural area, the free-cheeks and the front end of the epistome apparently forming only a very narrow band on the edge of the head-shield in front. Bailey[3] shows this band in a figure of a specimen from the Bala beds of the Onny River. But the inferior doublure, the epistome and epistomal sutures have not been observed or described in any specimen, and in the majority of specimens of the head only the middle-shield is preserved. The glabella, which is urceolate, does not show any lobation, and "para-glabellar areas" are absent or practically obsolete, but I have seen faint indications of them in a head-shield (No. 5) from Marshbrook in the Ludlow Museum.

A species referable to the same group as *H. bisulcatus* is *H. ascriptus*, Reed,[4] from the Dufton Shales of Melmerby, but it is only founded on head-shields somewhat resembling Salter's var. *β minor* of *H. bisulcatus* to which reference has above been made.

The middle-shield doubtfully referred by Salter to *H. Edgelli* (Salter, op. cit., pl. x, fig. 10, p. 108) and obtained from the Bala beds of Horderly, must also be placed here.

A new species allied to *H. Sedgwicki*, from the Bala beds of the Vyrnwy Dam, near Rhayader, has been recognized in the Sedgwick Museum, and the description of it under the name *H. Tawneyi* is now awaiting publication.

The second section of *Brongniartia* has as its type *H. rudis*, Salter,[5] which was founded on two extremely imperfect and distorted casts of pygidia from Capel Garmon, Denbighshire, in the Sedgwick Museum. The Welsh specimens in the Jermyn Street Museum, which Salter mentions (op. cit.) as belonging to this species and some of which he subsequently figured in his monograph in 1865 (op. cit., pl. x, fig. 12, Nantyr, Llanarmon $\frac{5}{7}$; pl. x, figs. 14*a*, *b*, Cader Dinmael $\frac{5}{8}$), are likewise very poor; the second figured one is, however, better than the original types. The strongly and well-defined axis to the thorax, and the shorter pygidium with fewer axial rings and fewer pleural ribs are features separating it from the species *H. bisulcatus*. But

[1] Ibid., pl. i G, figs. 29, 30.
[2] Salter, Mem. Geol. Surv., vol. iii (2nd ed., 1881), p. 523, pl. 11*a*, fig. 8.
[3] Bailey, Fig. Char. Brit. Foss., i, pl. xiii, fig. 9*a*, 1875.
[4] Reed, GEOL. MAG., Dec. V, Vol. VII, p. 216, Pl. XVII, Figs. 4–8, 1910.
[5] Appendix to M'Coy's Syn. Pal. Foss. Woodw. Mus., p. v, pl. i E, figs. 20, 20*a*.

H. rudis is an unsatisfactory species owing to the impossibility of drawing up a proper diagnosis from the original material.

The pygidium (No. $\frac{5}{5}$ Mus. Pract. Geol.) figured by Salter in 1865 (op. cit., pl. x, fig. 18) from the "Caradoc Grits of Cressage, Shropshire", as probably referable to *H. rudis*, must certainly be separated, and may belong to the new species H. *biserratus* Reed MS. (the description of which awaits publication), but its edges are broken and imperfect.

The other British species referred by Salter to the second section of *Brongniartia* are the two from Budleigh Salterton pebbles described as *H. Brongniarti*, Deslong.,[1] and *H. Vicaryi*, Salter.[2] A third[3] unnamed species is described by Salter from the same locality, and a fourth from Gorranhaven,[4] both the latter being represented only by pygidia. According to Bigot,[5] Salter's *H. Brongniarti*, Desl., is not the same as Deslongchamps' type, but is referable to *H. serratus*, de Trom. The figures and description of *H. vulcani* (Murchison), promised by Salter (op. cit., p. 113) have never been published; it is stated[6] "to occur in the volcanic grit on the west flank of Corndon Mountain in a ravine east of Middleton", but I have not been able to trace the specimen.

The species of *Homalonotus* from the Grès de May, Normandy, including those from the British pebbles in the Budleigh Salterton Triassic conglomerate, and also those from Gorranhaven, belong to a group somewhat distinct from the typical *Brongniartia*, though (as stated above) Salter put them in his second section. They seem to be the earliest representatives of the genus, apart from any of the questionable genus *Neseuretus*. The characteristics of the group are the strong trilobation of the thorax and pygidium, and the short transverse or semicircular shape of the pygidium, together with its composition of few segments, and its vertical or steeply inclined but not completely infolded doublure. It may also be mentioned that the pleuræ on the pygidium are occasionally separated by furrows right up to the edge of the doublure, and sometimes show traces of division at their ends, and that the furrow which marks off the articulating band at the front end of the axis is continued laterally as a strong furrow across the large bevelled articulating facet at the anterior lateral angles of the pleural lobes. In the case of the head-shield it appears that the facial sutures cut the lateral margins slightly in front of the genal angles, which are well rounded; the glabella is parabolic, semioval, or rounded-trapezoidal, and the axial furrows are not sinuated as in *H. bisulcatus*. The facial sutures unite in front marginally or just inside the margin in a regular uninterrupted curve, which may or may not be flattened. Most, if

[1] Salter, Quart. Journ. Geol. Soc., vol. xx, p. 290, pl. xv, figs. 1*a*, *b*, 1864; Mon. Brit. Trilob., p. 110, pl. x, figs. 15–17; pl. xiii, fig. 9.
[2] Ibid., p. 111, pl. xiii, fig. 10.
[3] Ibid., p. 112, pl. x, fig. 18.
[4] Ibid., p. 112, woodcut, fig. 26.
[5] Bigot, Bull. Soc. Géol. France, ser. III, vol. xvi, p. 427, 1888.
[6] Murchison, *Silur. Syst.*, 1839, p. 663; id., *Siluria*, 2nd ed., 1859, pl. ii, figs. 3, 4.

not all, of the species seem to show no glabellar lobes, though Salter[1] describes furrows and lobes in his *H. Brongniarti*, Desl.

In *H. Deslongchampsi*, de Trom., Morière[2] describes the thoracic pleuræ as having a little angular projection at the point where they begin to bend back, which fits into a notch in the preceding pleuræ, but it is not clear from Bigot's descriptions and figures (op. cit.) if this structure is present in other species.

The Gorranhaven specimens,[3] which are most probably referable to this group, are too poor for precise determination.

Barrande[4] in his supplement figures and describes a perfect individual of the Ordovician species *H. bohemicus*, Barr.,[5] from Stage Dd 2, which Salter referred to the second subdivision of *Brongniartia*, and this specimen is particularly interesting because it shows the epistomal sutures starting at right angles from the points at which the facial sutures bend inwards near the anterior margin and crossing the pre-sutural band to pass to the inferior surface of the doublure. We may, with much probability, assume that the closely allied other species of this group have the structure of the front of the head-shield and the behaviour of the sutures on a very similar plan.

A considerable number of species seem to belong to this group, and all those marked * come from the Grès de May or its undoubted equivalents:—

**H. serratus*, de Trom.
**H. Bonnisenti*, Morière.
**H. incertus*, Bigot.
**H. Brongniarti*, Desl.
**H. Vicaryi*, Salt.
**H. Deslongchampsi*, de Trom.
**H. Morierei*, Bigot.
**H. besnevillensis*, Bigot.
H. Barroisi, Lebesc.[6]
?*H. Viellardi*, De Trom.
?*H. draboviensis*, Novak[7] (Bohemia).
?*H. bohemicus*, Barr. (Bohemia).
H. Brongniarti, De Vern. *non* Desl.[8] (from Sierra Morena).
H. biserratus, Reed, sp. nov., Shropshire.
H. [*Neseuretus*] *quadratus* (Hicks), Ramsey Is.

5. *Kœnigia*, Salter, 1865.

The type of Salter's section *Kœnigia* is *H. Knighti*, König,[9] of the Upper Ludlow Beds of England and Sweden, which König chose as the type of his genus *Homalonotus*. The latter name is now generally employed in a more comprehensive manner, the characters of *H. Knighti* being extremely uncommon and scarcely representative of the whole assemblage of species. The name *Kœnigia* therefore seems desirably applicable in this restricted sense to the group of forms resembling *H. Knighti*. Salter included his *H. ludensis* in *Kœnigia*,

[1] Salter, Quart. Journ. Geol. Soc., vol. xx, p. 290, pl. xv, fig. 1, 1864.
[2] Morière, Bull. Soc. Linn. Normandie, ser. III, vol. viii, p. 383, pls. i, ii, 1884.
[3] Collins, Trans. Roy. Geol. Soc. Cornwall, 1893, p. 53 (reprint).
[4] Barrande, Syst. Silur. Bohême, Suppl. 1, p. 37, pl. i, fig. 6.
[5] Barrande, Syst. Silur. Bohême, vol. i, p. 580, pl. xxxiv, figs. 40–2.
[6] Lebesconte, Bull. Soc. Géol. France, ser. III, vol. xiv, p. 801, pl. xxxvi, figs. 12, 13, 1857.
[7] Novak, Böhm. Trilob., i (Beitr. Palæont. Oest. Ung., Bd. iii, 1881), p. 27, t. viii, figs. 9*a–c*.
[8] De Verneuil, Bull. Soc. Géol. France, ser. III, vol. xii, p. 971, pl. xxiii, fig. 1*a*, 1855.
[9] König, *Icones Sectiles*, 1825, pl. vii, fig. 85.

but this reference seems unwarranted, the head-shield so far as we know it not possessing any of the typical characters. The definition of *Kænigia* given by Salter[1] was as follows: "Convex; head wide, transverse, with concave and tricuspidate front, glabella subquadrate, well-defined; eyes rather approximate, on gibbous cheeks; tail pointed, many ribbed." Salter[2] described the species *H. Knighti* at some length, but he did not give a clear description or figure of the peculiarly characteristic structure of the anterior part of the head-shield, which is well seen in some British specimens. Moberg & Grönwall[3] published some better illustrations of this trilobite, and showed distinctly the peculiarities of the anterior margin and the course of the facial sutures. It is seen that the remarkable tricuspid front is due to the median projection of the anterior end of the epistome (= rostral shield) which is bounded on each side on the inferior surface by the epistomal sutures. The triangular lateral projections are formed by the anterior ends of the free-cheeks being angulated forwards, and also bent up and down in a zigzag manner. The marginal doublure thus has an unusual angulated appearance in a frontal as well as in a superior view. The facial sutures unite by a transverse commissure before a very narrow pre-glabellar area, and this transverse suture (which must be regarded as the direct continuation of the true facial sutures bent rather suddenly inwards) consists of two gently sigmoidal halves meeting in the middle at an angle so as to form a small median point. The sudden change in the direction of the facial sutures may be due to the more rapid forward growth of the lateral portions of the head-shield as compared with the median portion, and may be directly connected with the anterior projection of the front ends of the free cheeks on the margin.

A similar tricuspid front and projecting epistome is found to exist in the species *H. Johannis*, Salter,[4] as an examination of the types and other specimens from the original locality in the Jermyn Street Museum proves; Salter did not show this tricuspidation in his figures, the anterior end of the epistome of his specimens being imperfect, and the lateral projections of the anterior margin of the head-shield being blunter and less prominent than in *H. Knighti*. But he figured the inferior doublure and epistomal sutures clearly in his figures 2 and 7.

A character of some importance which is present in *H. Knighti* and less distinctly in *H. Johannis*, is the more or less circumscribed subquadrate or rounded area on each side of the base of the glabella. These areas are differently ornamented to the rest of the head-shield, and resemble in position and shape the "alar" areas of *Harpes*. But to avoid prejudging their homology they are here termed the *paraglabellar areas*. We shall have occasion to remark on their presence in other subgenera.

[1] Salter, Mon. Brit. Trilob., p. 106.
[2] Ibid., p. 119, pl. xii, figs. 2–10, pl. xiii, fig. 8.
[3] Moberg & Grönwall, Om Fyled. Gotl., Lunds Univ. Arssk., N.F., Af. ii, Bd. v, No. 1, pp. 72–7, pl. v, figs. 1–4, 1909.
[4] Salter, op. cit., p. 117, pl. xiii, figs. 1–7.

The trilobation of the thorax is nearly lost in *H. Knighti* (which is paralleled by *H. planus*, Sandb., otherwise quite distinct), and the axis of the pygidium is scarcely marked off from the lateral lobes, the axial furrows in both cases being almost obsolete. The elongated triangular shape of the pygidium, its numerous annulations, and its produced and pointed extremity are features which are common also to *Trimerus*, *Digonus*, and *Burmeisteria*, sens. str., as noticed below.

H. Johannis differs from *H. Knighti* in possessing a broad preglabellar area, which results in the head-shield having a triangular appearance instead of being transverse and so much shortened as to be broader than long. In consequence of the length of the head being not thus abnormally reduced, the convergent facial sutures approach each other in front more closely before bending abruptly inwards to form the transverse commissure. We shall observe a similar modification in members of *Digonus* and *Burmeisteria*.

The hypostome of *H. Knighti* has been figured by Lindström,[1] and is of the same type as that of *H.* (*Trimerus*) *delphinocephalus*.

(*To be continued.*)

V.—Mountain Building.

By R. M. Deeley, M.Inst.C.E., F.G.S.

In an article by Dr. H. Jeffreys in the Geological Magazine for April, pp. 215–19, an attempt is made to show that the discovery of radio-active materials in the earth's crust favours the "contraction and puckering" theory of mountain building. With regard to O. Fisher's view he writes, "It rests entirely on Kelvin's theory of the cooling of the earth, which has had to be completely revised on account of the discovery of the extensive distribution of radio-active matter in the earth's crust. The time available has been found to be about twenty times greater than on Kelvin's theory, and the cooling has therefore had time to extend to a much greater depth and to produce a very much greater compression." We are also told what the reduction in the earth's diameter has probably been, and the actual depth of Fisher's level of no strain.

Reference is also made to the three very valuable and interesting papers by Arthur Holmes published in the Geological Magazine. But Holmes is by no means as dogmatic as Dr. Jeffreys. Holmes writes: "If each grain of the earth's substance were as rich in radio-elements as are the rocks which have been examined, the earth's total output of heat from this source alone would, in any given period, be about 300 times as great as the amount actually lost by conduction to the surface and radiation into space."

"This astonishing result pulls us up sharply, for it is manifestly absurd to believe that our planet is becoming hotter at the appalling rate implied in these figures, or, indeed, that it is becoming hotter at all." To get over the difficulty it is *suggested* that the radio-active elements only exist in the outer portion of the crust of the earth, and in quantities insufficient to cause the earth to become hotter, and

[1] Lindström, Handl. k. Svensk. vet. Akad., Bd. xxxiv, No. 8, p. 57, t. iv, figs. 20, 21, 1901.

Dr. Jeffreys takes this *suggestion* to be a *fact*, and would have us believe that the thickness of this radio-active layer has been fairly accurately measured and that consequently it is possible to calculate the depth of the level of no strain.

The discovery of radio-active elements in the rocks of the earth has *not* rendered the compression theory any more probable. In its naked simplicity it appears to show that the earth is getting hotter and increasing in diameter at an "appalling rate". I am inclined to agree with Holmes that the radio-active elements are mainly concentrated near the earth's surface; but think that the exact amount of concentration is uncertain. An expanding earth would account for the formation of "rift valleys", normal faults and lines of volcanic activity or crustal weakness.

The theory I have supported to the effect that the folding and contortion of the rocks of the earth's crust have been largely due to vertical flow resulting from denudation and horizontal flow by the spreading of elevated areas, would account for the peculiarities our rocks present *even if the earth were slowly expanding*.

Dr. Jeffreys states that "substances possessing any elasticity are called solids". "If it is absent . . . the substance is a fluid." Contrast this statement with the following from Maxwell's *Theory of Heat*, edited by Lord Rayleigh, p. 302: "Gases and liquids, and perhaps most solids, are perfectly elastic, as regards stress uniform in all directions, but no substance which has yet been tried is perfectly elastic as regards shearing stress, except perhaps for exceeding small values of the stress." Dr. Jeffreys will find that the difference between a solid and a liquid is clearly stated on p. 303 of the above quoted work. Both solids and liquids are brittle and elastic. This can, in the case of a liquid, be clearly seen as regards pitch, but not in the case of water; but all liquids are elastic even under tangential stress.

In my article on "Mountain Building" which Dr. Jeffreys criticizes, I did not venture to introduce any new theories concerning the properties of matter, and I think that my critic should have pointed out that his views are not those of our textbooks. To my mind his theories concerning the solid and liquid states are quite inadmissible.

NOTICES OF MEMOIRS.

A Triassic Isopod Crustacean from Australia.

A Fossil Isopod belonging to the Freshwater genus *Phreatoicus*. By Chas. Chilton. Journ. Proc. Roy. Soc. N.S. Wales, li, pp. 365–88, 13 text-figs., 1918.

Of the six (or perhaps seven) sub-orders composing the order Isopoda, only the Flabellifera and Valvifera have been definitely recognized in a fossil state. The Flabellifera are represented by several genera as early as the Jurassic, while the Valvifera are known only by a single species from the Oligocene. Professor C. Chilton now announces the discovery, in the supposed Rhætic rocks of New

South Wales, of a representative of the remarkable little sub-order, the Phreatoicidea. To make clear the importance of this discovery it is necessary to give a brief account of the existing members of the group.

The genus *Phreatoicus* was established thirty-five years ago, by Professor Chilton himself, for a blind species which he found inhabiting subterranean waters in New Zealand. Other species, some of them blind and some with functional eyes, were subsequently discovered in streams and lakes of New Zealand, New South Wales, Victoria, and Tasmania, and two species of terrestrial habitat were also found. Three of the species were referred to as many genera distinct from *Phreatoicus* and forming with it the family Phreatoicidæ, for which Mr. Stebbing in 1893 established the Tribe (now ranked as a sub-order) Phreatoicidea. In 1914 Mr. K. H. Barnard greatly extended the known range of the group by discovering a species of *Phreatoicus* living in streams on Table Mountain at Cape Town.

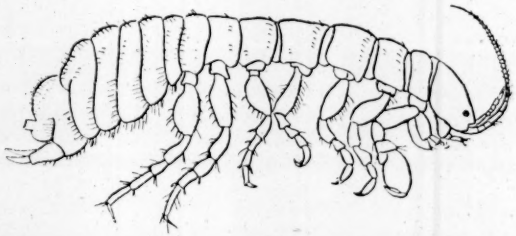


Fig. 1.—*Phreatoicus australis*, Chilton. Recent. Mt. Kosciusko, New South Wales. × 4. (After Chilton.)

The Phreatoicidea are distinguished from all other Isopods by having the body more or less compressed from side to side, and resembling in general appearance that of an Amphipod. This resemblance, however, is no more than superficial, and the structure of the animals shows that they are in no way closely related to the Amphipoda.

As in nearly all Isopods, seven somites are distinct in the thoracic region, and the telson is not separated from the last abdominal somite. In the Phreatoicidea, however, the first five abdominal somites are not only distinct and movable but they are of considerable size. This is of some importance as a primitive character, since the abbreviation of the abdominal region is one of the most characteristic features distinguishing the Isopoda from the other orders of Malacostraca. Even when, as in many Flabellifera, the abdominal somites are distinct from one another, they are crowded together, and the greater part of the length of the abdomen is formed by the enlarged terminal segment. The great development of the side-plates (pleura) of these abdominal somites in the Phreatoicidea, and the fact that they are directed downwards instead of laterally, are characters of less morphological significance, but they contribute to the Amphipod-like aspect. Another character

that may be regarded as primitive is found in the first or coxal segments of the thoracic legs. These are all of small size and, on the last six segments at any rate, are movably articulated with the body. In this character the Asellota resemble the Phreatoicidea, but in other Isopods these segments are expanded into broad "coxal plates" and more or less completely fused with the somites that carry them. Finally, the last pair of abdominal appendages (uropods) project from near the end of the body as bifurcate styles, like the uropods of certain Asellota, and still more like those of Amphipods.

In nearly all other respects—in the structure of antennules, antennæ, mouth-parts, thoracic legs, branchial abdominal limbs, and even sexual appendages—the Phreatoicidea are commonplace Isopoda, not differing essentially from many representatives of the central and typical sub-order, the Flabellifera. That they retain certain features which we believe to be primitive, or which point the way to groups outside the order itself, has already been stated, but this is true also of the Asellota and of the Flabellifera, and it is perhaps impossible to rank any one of these three sub-orders as, on the whole, more primitive than the others.

FIG. 2.—*Phreatoicus wianamattensis*, Chilton. Rhætic (?). St. Peter's Brickworks, Sydney. × 3½. (After Chilton.)

The habitat and the geographical distribution of the Phreatoicidea are also noteworthy. Isopods of truly freshwater habitat are few, and in no other case are they conspicuously different in structure from marine representatives of the group. With the possible exception of the single family Asellidæ, they are scattered, and no doubt recent, immigrants from the sea. The Phreatoicidea, on the other hand, are not known to have any near relatives among the marine Isopoda, and it is this that gives special significance to their remarkable distribution in New Zealand, South-Eastern Australia, Tasmania, and South Africa.

In describing the first known species of *Phreatoicus*, Professor Chilton stated that the group "must be of very considerable antiquity". This prediction he has now had the good fortune to verify in a striking manner. The specimens which he describes were detected by Mr. R. J. Tillyard while investigating the fossil insect fauna of Queensland and New South Wales, and were found in the Wianamatta Shale of St. Peter's Brickworks, Newtown, Sydney. The strata in which they occur were at first referred to

the Trias-Jura, and Professor Chilton quotes Mr. Tillyard's opinion that "evidence is accumulating that will probably place them in the Upper Trias, probably as the nearest Australian equivalent of the Rhætic". Dr. Smith Woodward, who has reported on the fossil fishes from the same beds, agrees that the fish fauna, if it had been found in the Northern Hemisphere, could not possibly have been regarded as of later than Rhætic age.

The largest specimen obtained must have measured about 30 mm. in length when complete. After examining a long series of specimens, Professor Chilton shows that, in the general form and segmentation of the body, the large size of the abdominal somites with their downwardly directed side-plates, the size and shape of the terminal segment and the uropods, the short antennæ (or antennules), and the form and proportions of the chief segments of the legs, the fossils closely resemble the living Phreatoicidea. There is indeed nothing to forbid their inclusion in the type-genus, to which he assigns them under the name *Phreatoicus wianamattensis*.

It seems probable from the presence of insects, of such Mollusca as *Unio*, and of numerous plant remains, that the beds in which the fossils are found are of freshwater or estuarine origin, so that even as early as the Triassic period the Phreatoicidea had adopted, or were on the way to adopt, the freshwater habitat to which they are at the present day confined.

While *Phreatoicus* is thus one of the oldest, if not the very oldest, of fossil Isopods yet discovered, and while it undoubtedly presents certain primitive structural characters, it should be noted that it throws no light on the phylogeny of the order. It is, indeed, very far from being an ancestral type, and it only emphasizes the fact that the evolution of the group goes a very long way back in geological times. No doubt among these early Isopods, as among those now living, a vast number of forms were two small and too delicate in structure to be readily preserved as fossils, and, except for some lucky chance, it is likely that we may never be able to trace, with any clearness, the lines of evolution followed by the various sub-orders.

In reporting the discovery of a species of *Phreatoicus* living at the Cape, Mr. K. H. Barnard called attention to its probable bearing on the antiquity of the group and referred to the former extension of "Gondwana land" over the areas where species of the genus now occur. We now learn that they existed, probably as freshwater animals, within the same area at a time when that extension may have been still unbroken. Whether at that remote epoch their geographical range was still wider, we cannot tell. If it was, then it becomes a most extraordinary coincidence that their fossil remains should first be found in a district where the living animals exist to-day.

REVIEWS.

I.—Petrography of the Pacific Islands. By R. A. Daly. Bull. Geol. Soc. America, vol. xxvii, p. 325, 1916.

IN this paper the author puts forward a proposal for a complete scientific exploration, geological, botanical, zoological, and anthropological, of the islands composing the regions of Polynesia, Melanesia, and Micronesia. These are scattered over an area composing nearly one-sixth of the earth's surface, and the information at our disposal concerning them is still very incomplete. The greater part of the paper is taken up by a discussion of the petrography of this vast region, so far as it is known. It is pointed out that what may be called "continental" rocks, namely, plutonic, metamorphic, and sedimentary types apart from coral-rock, are only found in islands lying to the west of a line joining the easternmost of the Fiji group to the Mariana Islands: all of these are fragments of an ancient continent that broke up in Tertiary times.

In several hundred other islands volcanic rocks have been recorded: all the known occurrences are tabulated, and it appears that the dominant types are olivine-basalt and pyroxene-andesite. Many other varieties related to these, mostly of basic composition, have also been recorded, and it is suggested that the andesites and the ultrabasic lavas are differentiates of a primary basaltic magma underlying the whole Pacific basin. The scarcity of acid lavas is noteworthy: it suggests that in this region the ordinary crust of quartzose sediments found in continental areas is absent. This is in accordance with the high density of the Pacific area as shown by geodetic observations. From the evidence adduced it is clear that this is a pre-eminently subalkaline province, and the author's well-known theory of syntectic differentiation brought about by absorption of limestone is applied to explain the genesis of a certain number of occurrences of typically alkaline rocks, such as basanite, nepheline-basalt, and varieties containing haüyne.

R. H. R.

II.—The Mineral Industries of the United States. Sulphur: an Example of Industrial Independence. By Joseph E. Pogue. Bulletin 102, pt. iii, United States National Museum (Smithsonian Institution). pp. 10 and 3 plates. Washington, 1917.

THE falling off in the imports of sulphur from Sicily and of pyrites from Spain consequent on the War has led to a great development of the home supplies of sulphur in the United States, and particularly of the native sulphur deposits of the Gulf Coast region in Louisiana and Texas. Here the sulphur occurs in dome-shaped masses in association with petroleum, rock-salt, and gypsum. Many of the domes consist of a core of rock-salt with lenses of gypsum and masses of limestone containing petroleum. In two instances, at Sulphur, La., and Bryan Heights, Texas, bores showed the presence of great masses of pure sulphur beneath several hundred feet of quicksand. These masses are supposed to be essentially of

igneous origin, and the doming of the rocks is attributed to the force of crystallization of minerals from supersaturated solutions. The petroleum, however, is probably of later date. Since for various reasons ordinary mining is impossible, the sulphur is extracted by the Frasch process, which consists essentially in forcing superheated water through a pipe to the sulphur horizon and lifting the sulphur by means of compressed air, when it is pumped into large bins to cool and then loaded straight into trucks. Under the present abnormal conditions it is possible that much of this exceptionally pure sulphur will have to be used for the manufacture of sulphuric acid, an uneconomic proceeding which would be quite unjustifiable in normal times.

R. H. R.

III.—The Geology of Pigeon Point, Minnesota. By R. A. Daly. *American Journal of Science*, vol. xliii, p. 423, 1917.

THIS paper gives the results of a further investigation of the well-known intrusion of Pigeon Point, originally described by Bayley (Bulletin 109, U.S. Geol. Survey). The main problem is as to the nature of the "red rock", a granitoid type with much micropegmatite. The igneous mass is concluded to be a sill, not a dyke as supposed by Bayley; its upper and lower surfaces are found to be concordant with the bedding of the Animikie rocks, into which it is intruded. The most striking feature is the regular variation in the character of the rock from below upwards; the base is olivine-gabbro, followed by gabbro, intermediate rock, and finally the highly acid red rock. This variation in composition is due to gravitative differentiation, acting on a gabbroid magma which had been modified by assimilation of sedimentary material derived from the roof of the sill by stoping. The differentiation is probably largely due to gas-action: the presence of much gas is shown by the abundance of drusy cavities, and peculiar "ribbon" injections, a few centimetres wide, also indicate great pressure in the magma. In all the rock-types are found xenoliths of Animikie quartzite coated with a shell of red rock. This suggests a diffusion of silica from the xenolith into the basic magma. The red rock appears to have remained liquid longer than the more basic types, owing to concentration in it of gas, which lowered its freezing-point. Consequently dykes and veins of red rock are found cutting the gabbro as well as the sediments. The red rock is not merely fused sediment as supposed by Bayley. Neither differentiation nor fusion alone is sufficient to explain all the facts, and the whole phenomenon is an example of syntexis, that is assimilation followed by differentiation of the mixed magma thus formed.

R. H. R.

IV.—On a possible Causal Mechanism for Heave-fault Slipping in the California Coast-range Region. By H. O. Wood. Bull. Seismol. Soc. America, vol. v, p. 214, 1915.

THIS paper has special reference to the origin of the fault-slip that caused the disastrous San Francisco earthquake of 1906. The theory is based on the principle of isostatic readjustment

following redistribution of mass by erosion and deposit. It is pointed out that in the Sierra Nevada and in the Coast Ranges denudation is very active, while most of the material thus set free is deposited either in the Great Valley of California or in the sea close to the coast. The overloading must be specially conspicuous in and near San Francisco Bay. Owing to this overweighting the areas of deposition undergo down-warping, while the denuded areas tend to rise, thus involving a compensating creep in the plastic depths. It is concluded from various lines of evidence that this creep or undertow must be greater in a direction parallel to the axes of the ranges than perpendicular to these; accordingly a state of tension is produced highly favourable to the formation of slip-faults with lateral displacement, such as the one that formed so conspicuous a feature of the San Francisco earthquake. A considerable amount of subsidiary evidence is put forward in support of the main idea, partly physiographic, derived from a study of Californian topography, and partly geodetic, depending on the results of many elaborate investigations of anomalous distribution of gravity and allied phenomena in this part of the United States.

R. H. R.

REPORTS AND PROCEEDINGS.

I.—The Royal Society.

April 25, 1918.—Sir J. J. Thomson, O.M., President, in the Chair.

The Bakerian Lecture was delivered by the Hon. Sir Charles Parsons, K.C.B., F.R.S., on "Experiments on the Production of Diamond".

In his lecture the author alluded to some of the results of experiments described in papers by him to the Royal Society in 1888 and 1907, more particularly to those on the decomposition by heat of carbon compounds under high pressure, and on the effect of applying pressure to iron during rapid cooling.

A description is given of experiments designed to melt carbon under pressures up to 15,000 atmospheres by resistance heating and by the sudden compression of acetylene oxygen flame, also by the firing of high velocity steel bullets through incandescent carbon into a cavity in a block of steel.

Allusion is made to experiments on chemical reactions under high pressure and their results. The pressures occurring in rapidly cooled ingots of iron and experiments bearing upon this question are discussed. Experiments at atmospheric pressure and experiments *in vacuo* are described.

The main conclusions arrived at are: that graphite cannot be converted into diamond by heat and pressure alone within the limits reached in the experiments; that there is no distinct evidence that any of the chemical reactions under pressure have yielded diamond; that the only undoubted source of diamond is from iron previously heated to high temperature and then cooled; and that diamond is not produced by bulk pressure as previously supposed, but by the

action of the gases occluded in the metal and condensed into the centre on quick cooling.

A list of about one-half of the experiments is given in the Appendix.

II.—Geological Society of London.

April 17, 1918.—G. W. Lamplugh, F.R.S., President, in the Chair.

The following communication was read:—

"The Evolution of the Liparoceratidæ." By Arthur Elijah Trueman, M.Sc., F.G.S.

The Ammonites considered include several sub-parallel series, of which four genera were indicated by Mr. S. S. Buckman in *Yorkshire Type Ammonites*. The details of ontogeny and the sutures, which had not hitherto been compared, have been employed in constructing tables showing both the biological and the stratigraphical relations of the various species; a revision of the existing classification is proposed.

The early members of each series are similar "capricorn" forms with slender whorls and stout ribs (for instance, *A. capricornus*, *A. latæcosta*, *A. maculatus*). In somewhat later examples the outer whorl is swollen, and has paired tubercles (for instance, *A. heterogenes*). From this stage the tendency is to shorten the period with slender capricorn whorls by accelerating the development of bituberculation and prolonging the period of pre-costate globose whorls; thus the most advanced members of each series are stout bituberculate forms (for instance, *A. striatus*, *A. bechei*), which do not pass in development through a capricorn stage.

The following genera may be recognized; each includes ammonites of the three types mentioned above:—

1. An earlier group, with tubercles paired in the involute stages; Radstock (Somerset) is the only British locality where these ammonites have been found.

Parinodiceras, gen. nov. Elevated whorl, paired tubercles, the inner and outer rows widely separated. Genoholotype. *Ammonites striatus parinodus*, Quenstedt (1884, pl. xxviii, fig. 6).

Gen. nov. Round whorl, with the rows of tubercles placed close together. Genoholotype, a specimen to be figured as a new species.

2. A later group, with unpaired tubercles in the involute stage. These genera are most readily distinguished by sutural characters, namely, the relative depths of the external lobe (EL) and the first lateral lobe (IL), and by the width of the external saddle (ES).

(*a*) With narrow ES (not reaching to the outer tubercles).

Liparoceras, Hyatt. IL and EL about equal in depth. Genolectotype, *Ammonites striatus*, Bronn.

Becheiceras, gen. nov. IL deeper than EL. Genoholotype, *Ammonites bechei*, Wright. (*Lias Ammonites*, pl. xli, fig. 1.)

Anisoloboceras, gen. nov. IL much deeper than EL, the ventral lobules of IL almost meeting under EL. Genoholotype, *Ammonites nautiliformis*, J. Buckman.

(*b*) With wide ES, reaching to the outer tubercles.

Ægoceras, Waagen. EL and IL about equal in depth, IL symmetrical. Genolectotype, *Ammonites planicosta*, d'Orbigny.

Androgynoceras, Hyatt. IL and EL about equal in depth, IL asymmetrical. Genolectotype, *Ammonites hybrida*, d'Orbigny.

Oistoceras, S. S. Buckman. Ribs with sharp peripheral curve. Suture similar to *Androgynoceras*. Genoholotype, *Ammonites figulinus*, Simpson.

Amblycoceras, Hyatt. Ribs with slight peripheral curve. IL shallower than EL. Genoholotype, *A. capricornus*, Hyatt, 1900.

These ammonites generally occur in the upper part of the Lower Lias, where it has been usual to recognize a *capricornus* zone overlying a *striatus* zone. Careful collecting has shown, however, that there are several horizons with capricorn ammonites of different series and several with the involute forms evolved from them, as shown below:—

margaritatus zone	Bituberculate ammonites of the *A. nautiliformis* series.		
	,,	,,	*Oistoceras*.
davæi zone	Capricorn	,,	*Oistoceras*.
	Bituberculate	,,	the *A. bechei* series.
	,,	,,	*Ægoceras* and *Androgynoceras*.
	,,	,,	*Amblycoceras*.
	Capricorn	,,	*Amblycoceras*.
	,,	,,	*Ægoceras*, *Androgynoceras*.
	,,	,,	*Beaniceras*.
ibex zone	Bituberculate	,,	*Liparoceras*.
	Capricorn	,,	*Liparoceras*.
	Bituberculate	,,	the first group (with paired tubercles).

In no locality that has been examined is the complete sequence shown. The absence of some groups is due to the original distribution of the ammonites; in other cases it is due to non-sequences (for example, the upper part of the *davæi* zone is not represented in Gloucestershire).

Two groups of Lias Ammonites are recognized, namely: (i) those which were evolved directly from a globose ancestor; this includes the Liparoceratidæ, Echioceratidæ, Hildoceratidæ, Polymorphidæ, Deroceratidæ; and (ii) those which passed through an intermediate broad-ventered (cadicone) stage; these include the Amaltheidæ and Dactyloidæ (with *Beaniceras*).

III.—Zoological Society of London.

April 9, 1918.—Dr. A. Smith Woodward, F.R.S., Vice-President, in the Chair.

Dr. A. Smith Woodward, F.R.S., V.P.Z.S., exhibited fossil rostral teeth of the sawfishes *Eopristis* and *Pristis*, and referred to the progressive changes in the rostral teeth of the Pristidæ during geological time.

Mr. G. A. Boulenger, F.R.S., exhibited the head of an example of *Hydrocyon goliath*, Blgr., from the Congo, a fish attaining the length of 4 feet. The object of the exhibition was to show the enormous

shark-like teeth, to which special interest attaches, owing to a similarity, recently pointed out by Dr. Eastman, to fossil teeth occurring in the Upper Cretaceous, which would appear to indicate the existence of Characinidæ in that geological epoch, a range in time which Mr. Boulenger had predicted as probable thirteen years ago.

CORRESPONDENCE.

DEPOSIT OF GRANULAR IRON-ORE ON THE COAST OF BUENOS AYRES.

Sir,—The newspapers of Buenos Ayres have recently announced the discovery of a deposit of granulous iron-ore on the Atlantic seaboard of the province of that name. As the whole Argentine Republic has hitherto only been able to boast of one genuine occurrence of that valuable mineral, in the shape of the famous meteorite hurled into the Gran Chaco in the north (see section of same in the Geological Department of the British Museum (Natural History), South Kensington), popular curiosity was much aroused and excited.

As possibly the subject may contain some points of interest, I herewith furnish the more important details.

The locality is the sea-coast and both sides of the mouth of the River Quequen Grande, in (roughly) lat. 38° and long. 58°. And it is somewhat to the south of the recently named Chapadmalalense formation, the site of the Ameghino palæontographical controversy.

The total area of the deposits is estimated at some 5,000 hectareas. It is stated that the magnetic iron-ore is found distributed through the sand from the surface to an average depth of 10 metres (otherwise to where it rests on the "tosca" or loëss of the Pampean formation), and in a proportion of 30 per cent of mineral. The result, in accordance with these figures, would represent the colossal amount of 750 millions of tons. As, however, the preceding is the commercial phase, or view taken by the parties who have obtained the concession for exploiting the situation, it may be open to very considerable discount.

I have before me the analysis and reports furnished by various Government specialists and departments. On account of the length, etc., of these, I have selected in preference one emanating from London itself, and which is as follows:—

ANALYSIS OF TWO SAMPLES OF MINERAL.

	Marked 18.	*Marked 21.*
	%	%
Silica	1·36	1·10
Titanium oxide	17·66	18·14
Ferrous oxide	74·27	74·11
Manganous oxide	0·56	0·62
Alumina	0·22	0·16
Lime	0·38	0·34
Magnesia	0·42	0·33
Combined water, alkalies, and loss	5·13	5·20
	100·00	100·00

A special search was made for sulphur and phosphorus, giving the figures:—

	Marked 18.	*Marked 21.*
	%	%
Sulphur	0·055	0·074
Phosphorus	0·109	0·115

Both samples are titaniferous iron-ore of moderate quality.

ERNEST GIBSON.

25 CADOGAN PLACE, LONDON, S.W.1.
May 5, 1918.

OBITUARY.

PROFESSOR GEORGE ALEXANDER LOUIS LEBOUR,

M.A., D.Sc., F.G.S., VICE-PRINCIPAL OF THE ARMSTRONG COLLEGE, NEWCASTLE-UPON-TYNE.

BORN 1847. DIED FEBRUARY 7, 1918.

BY the death of Professor Lebour in his 71st year, on February 7, 1918, the scientific world loses a prominent and interesting figure. Born in 1847 and educated at the Royal School of Mines, he served from 1867 to 1873 on the Geological Survey of England and Wales. He was lecturer in geological surveying at the University of Durham College of Science (later, Armstrong College) in Newcastle from 1873 to 1879, and succeeded Dr. David Page as Professor of Geology in the University. This position he occupied until his death, so that for forty-five years he was connected with the College, and for thirty-nine years occupied the chair of Geology. In 1904 he was awarded the Murchison Medal by the Council of the Geological Society, and in the same year was elected Vice-Principal of Armstrong College.

The transference of heat through the crust of the earth occupied Lebour's attention early and led to measurements of underground temperature in northern coal-pits, and also in conjunction with Herschel, to the determination of the thermal conductivities of a great number of rocks. This important work, issued in a series of British Association reports from 1873 to 1881, is well known, and many of the data obtained are accepted as standard.

Lebour's name will always be associated with the geology of Northumberland and Durham. Besides his official maps, he brought out in 1877 an excellent geological map of the county of Northumberland, which is the embodiment of much strenuous, clear-sighted labour. He was joint author with William Topley of a widely quoted paper on the Great Whin Sill, which may be said to have definitely established its intrusive character. The stratigraphical relations of the Carboniferous rocks form the subject of many papers, in which the divisions of the system and the description and correlation of the important limestones, etc., are set forth with admirable lucidity. The economic aspects of the subject find expression in papers on the Redesdale Ironstones and the coals of the Bernician series, especially those associated with the Little Limestone. The future importance of these coals, which occur in